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LUMBER VALUES FROM COMPUTERIZED SIMULATION OF HARDWOOD LOG SAWI--ETC(U)
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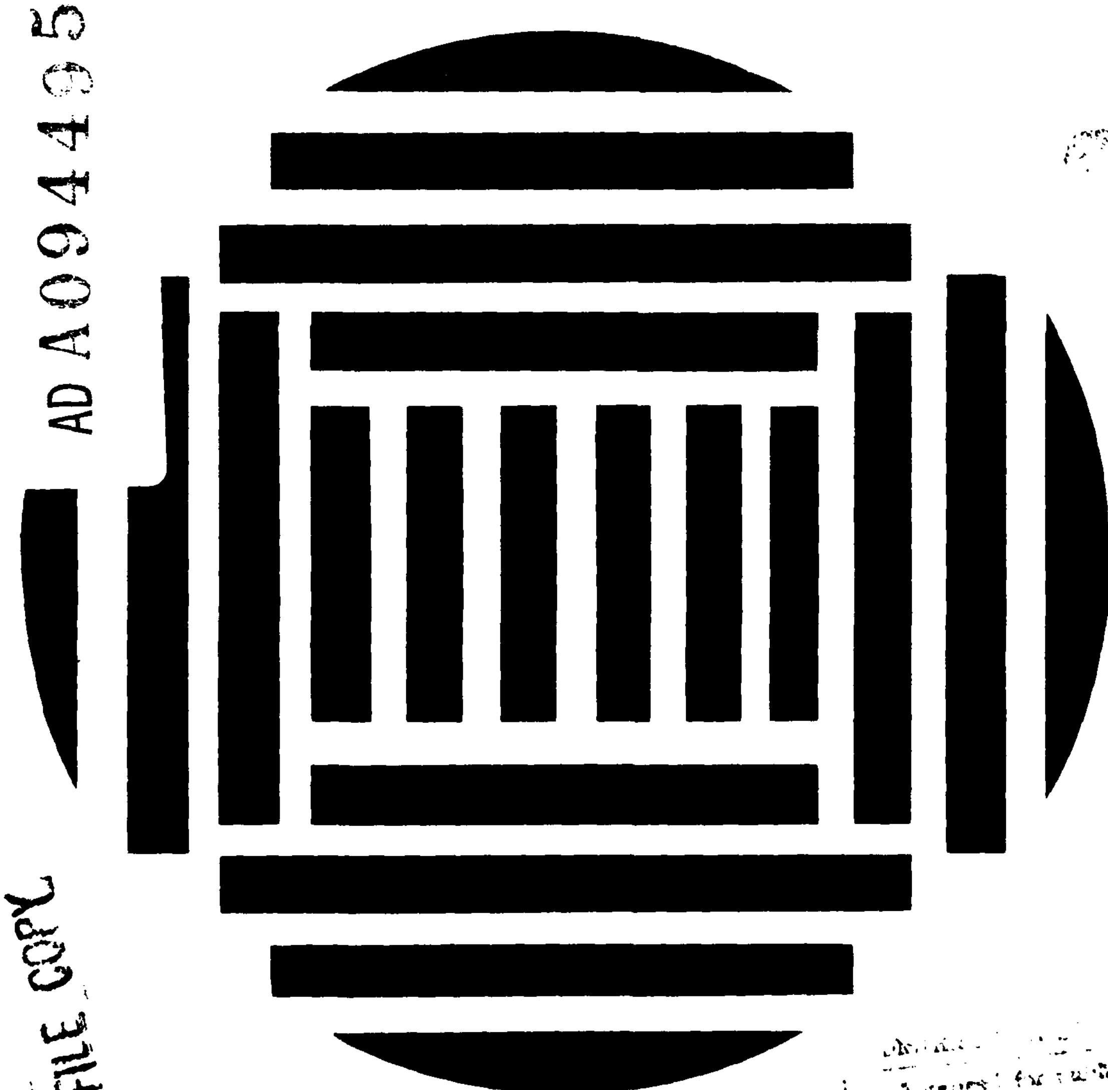

Abstract

Computer simulation sawing programs were used to study the sawing of mathematical models of hardwood logs by the live sawing and three 4-sided sawing methods. One of the 4-sided methods simulated "grade sawing" by sawing each successive board from the log face with the highest potential grade. Logs from 10 through 28 inches in diameter were sawn. In addition, a refinement in the live sawing called live rip, in which center-sawn boards are ripped to increase value, was studied.

Results generally indicate that all of the 4-sided methods studied gave similar lumber values. Live sawing was better than the 4-sided methods with good logs but inferior for 10- and 12-inch logs with large defective cores. Live sawing followed by ripping produced the highest lumber values in almost all cases.

This Research Paper is one in a series of three which describe the computer simulation of hardwood log sawing. Mathematically modeled logs with a selection of diameters, core defect diameters, and knot patterns were sawn by four sawing methods, and the resultant values were recorded.

The first paper, USDA Forest Service Research Paper FPL 355, "Simulation of hardwood log sawing," describes the sawing methods, and the background and development of these programs.

This second paper, FPL 356, "Lumber values from computerized simulation of hardwood log sawing," presents the results of the sawing in terms of volume yield and lumber value, and compares them for the four sawing methods.

The third paper, FPL 357, "Programs for computer simulation of hardwood log sawing," lists the programs, model assumptions, and program organization and variables.

Keywords

Computer simulation

Mathematical modeling

Hardwood sawing

Computer programs

Quadrant sawing

Cant sawing

Live sawing

Decision sawing

Grade sawing

Grade yield

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Lumber Values from Computerized Simulation of Hardwood Log Sawing

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Introduction

In the United States, most hardwood sawyers turn a log on the carriage a number of times in an effort to get the highest grade lumber available from the log. In this process (called "sawing for grade") the log is usually sawed on all four faces. It is generally assumed by lumbermen that this process yields the highest dollar value from the log even though a number of studies have suggested otherwise *(2-7, 10, 12, 13, 14, 17, 18, 20-23, 25, 27, 28)*.[3]

The simulation study of Richards (21) seems to indicate that, under average conditions, live sawing may exceed 4-sided sawing in value by about 3 percent, but if the four centrally located wide boards are reripped by a mathematical formula, the live sawing (now called live rip) surpasses 4-sided sawing by about 15 percent in value. Despite these interesting results, the issue is still in doubt. The logs simulated by Richards were somewhat above average in quality, there were no hidden knots (all knots came to the surface), and the 4-sided sawing methods used were strictly mechanical in nature and hence did not really simulate the sawing pattern a good sawyer might have used when uncovering hidden defects.

It is the purpose of this study to clarify these issues by using simulated logs with hidden knots, by turning the log on the carriage to saw the highest valued log face as a sawyer might do, and by making other modest improvements in defect input and in reripping simulation.

Methods

In real life, of course, a sawyer can turn his log to any position he wishes for the initial cut, but once he has developed a log face he is committed to all four faces for the log. After sawing the log he can not put it back together and saw it over again to see how it would come out had he elected to start from a slightly different rotational position. Computerized simulation allows the same log to be sawn by different methods and is one of the main justifications of a study such as this.

The simulation system and programs used allow any reasonable values for such log parameters as length, diameter, taper, knot location, knot length, and knot taper, as well as core defect size and location. Any reasonable values for board and kerf thickness, for rotational position on the sawmill carriage, and for lumber prices may also be used. The following descriptions only outline what the computer did to get the results in this particular

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[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
[3] Numbers in parentheses refer to literature cited at end of report.

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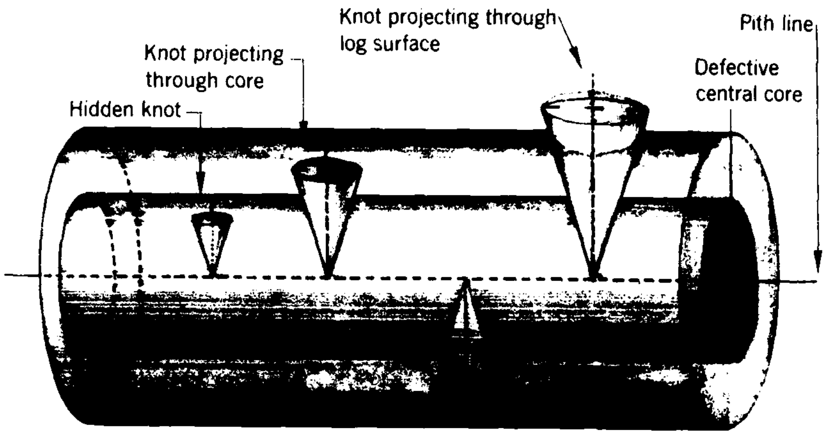

Figure 1.—An illustration of the method used to simulate a log, its knots, and the centered defective core area.
(M 147 659)

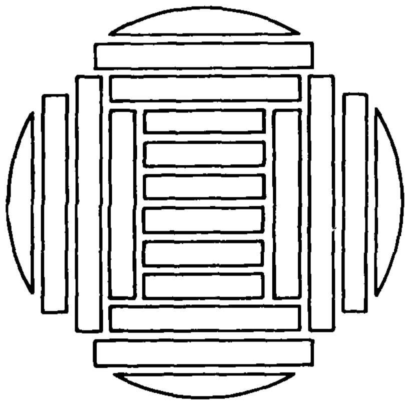

Figure 2.—End view of a log sawn by the quadrant sawing method.
(M 148 324)

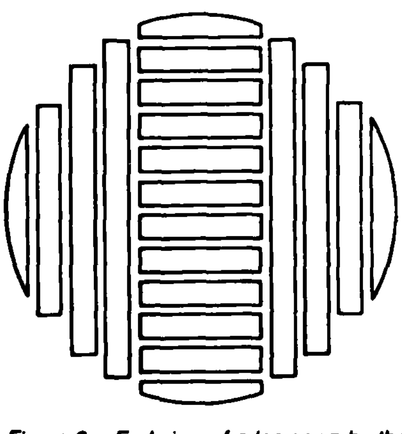

Figure 3.—End view of a log sawn by the cant sawing method.
(M 148 326)

report. Details of how the computer programs work (*24*) and copies of the program themselves (*1*) are available.

Log Model

Logs were simulated in a computer as truncated cones with a taper of 0.3° (approximately 1-1/2 in. of taper in the 12-ft logs used in this study). The logs ranged from 10 through 28 inches in diameter (inside bark) at the small end. In hardwood lumber grades, the minimum clear-face cutting is a rectangular piece 3 inches by 2 feet, clear on one face with the reverse side sound (*16*). The central core was assumed to be so defective that it yielded no allowable clear-face cuttings in a centrally located cylinder that extended the length of the log and was 1, 4, 6, or 8 inches in diameter.

Each knot was simulated as a cone with its apex of 24° at the pith (central axis) of the log (fig. 1) and tapering outward (yielding a knot approximately 3.4-in. in diameter at the surface of a 16-in.-diameter log). Each log had either 15 or 30 knots, the positions of which were randomized both longitudinally and periclinally (around the log). The length of each knot from the pith outward was selected at random in the following manner: A decimal fraction between 0 and 1 was selected at random and then squared. The resultant fraction was then multiplied by the log radius and the product added to 3 inches to yield the length of the knot. This means that any one knot could be terminated anywhere between 3 inches from the pith to 3 inches beyond the log surface, but that it had a reasonable probability of being hidden fairly deeply as the square of a decimal fraction is smaller than the fraction itself and hence the distribution is skewed toward knots that are shorter (i.e., hidden more deeply).

Sawing Methods

The following five sawing methods were used in the current study:

Quadrant Sawing

Because quadrant sawing requires the maximum number of turns on the carriage, it is an impractical method of sawing, but because of a rather uniform level of performance it is included as a reference. While the computer saws one quadrant at a time, the pattern sawed is the same as would be produced by turning the log after each board is cut and alternating 180° turns with 90° turns on the carriage until a central cant 5-1/8 inches thick remains which is sawed into boards by parallel saw cuts (fig. 2).

Cant Sawing

Of the 4-sided sawing methods, cant sawing requires the fewest number of turns on the carriage. By cutting a slab and board(s) from face 1 and then from face 3, a central cant is produced that has a selected thickness (in this study, 2 in. less than half the log diameter). This central cant is then turned 90° and sawed into boards (fig. 3).

Decision Sawing

The decision sawing method simulates the decisions of a human sawyer in grade sawing. Faces 1, 2, 3, and 4 of the log are sawed until the log is square and without wane at midlength. Each exposed face is then graded by the Forest Products Laboratory (FPL) computerized grading program (*8*, *9*, *22*) and the highest grade face selected for sawing. In case of a tie between the grades of two faces, the one with the largest surface measure is chosen. The selected face is sawed until the grade drops. Second, the program again grades every affected face and selects the highest grade face for sawing (surface measure decides ties) and continues sawing any given face until the grade drops. Third, log turning and sawing continue in like manner until a central cant remains that will yield exactly four equal boards when parallel sawed. Sawing is completed by sawing these four boards which may or may not be the same size as adjacent boards (fig. 4).

Live Sawing

In live sawing a saw kerf bisects the log along the central axis and the plane of each subsequent saw cut (and hence each board face) is parallel to this central cut (fig. 5).

Live Sawing with Reripping for Grade

In live rip, the log is sawed as in live sawing but the outer face of each board is checked for defect type. If the central core defect shows up on the outer face of the board, this defect is automatically ripped out and the resultant boards are regraded and revalued (fig. 6). If the rerip value exceeds the former value, it is used; otherwise the former value is used and it is assumed that no rerip would have been performed. In the computer, the programs for live sawing and live rip sawing are run simultaneously as one program, as the output for live sawing is used immediately to generate the rip data. They are reported here as two separate sawing methods because their results, when different, are reported separately in the tables and figures. For logs with 1-inch core defects, the reripping showed no improvement; hence live rip data are omitted to save needless repetition and only live sawing values are reported. While the reripping technique is a moderately good one, it is certainly not an optimum one and higher values could probably be obtained with a more nearly optimum reripping procedure.

All Methods

In all the sawing methods, any waney boards produced are parallel edged to limit the length of wane to 50 percent or slightly less along each edge of the board. In addition, if the board tip has excessive wane, it is cut back by 1-foot decrements until the sound wood is at least 2.5 inches wide at the tip and 3 inches wide at midlength, and the wane is not wider than 2 inches on each edge. If these edging and trimming procedures reduce the piece to less than 4 feet in length, then the piece is discarded as not being lumber.

Each study log generated in the computer was sawed by each of the sawing methods. In addition, for each sawing method, the log was completely sawed in 12 different rotational positions. Each subsequent sawing assumed the log to have been positioned on the carriage for the initial cut in a position rotated 15° clockwise from the initial position of the previous sawing of that log. This procedure means that if a particular knot were in the 0° position for the first sawing of the log, it would be in the 15° position for the second sawing, the 30° position for the third sawing, and on around to 165° for the twelfth sawing; there would be no point in going on to 180° as it would duplicate the 0° position (fig. 7). This clockwise rotation of the log is equivalent to rotating the position of the initial saw cut in a counterclockwise direction around the log. The computer not only calculated the average value for all 12 rotational positions, but it also kept track of the highest and the lowest valued position and reported them. The rotational position yielding the highest value is called Best (B), the average value Mean (M), and the rotational position yielding the lowest value Worst (W).

Log diameters of 10, 12, 14, 16, 18, 20, 24, and 28 inches were studied for 1-, 4-, and 6-inch core defects but the 10-inch-diameter logs were not studied for the 8-inch core as there would be only below-grade boards in such a log. For each size of log and core defect two numbers of knots were used (15 and 30 knots per log).

For the main part of the study, 1-inch boards were sawn using a 3/8-inch saw kerf. While this is not identical (because of a slight difference in wane generated), it is approximately equivalent to cutting 1-1/8-inch boards with a 1/4-inch kerf or 1-1/16-inch with a 5/16-inch kerf. In other words, it is approximately what might be expected from a well-alined and run circular headsaw.

Because of the continued good showing of the live sawing methods (especially live rip), it was decided to set up a comparison with a log-frame gang saw and thereby determine, also, the exact gain in volume yield resulting from a reasonable reduction in saw kerf. For this reason, a 1/4-inch saw kerf was also used for live sawing and live rip sawing for some of the logs. This is approximately equivalent

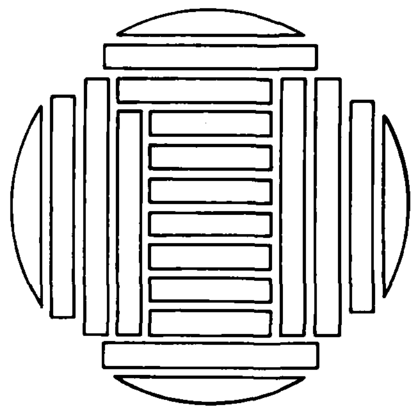

Figure 4.—End view of a log "grade sawn" by the decision sawing method.
(M 148 325)

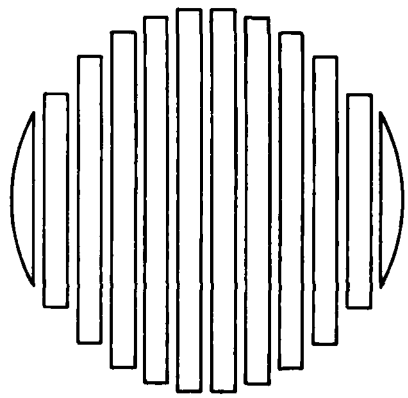

Figure 5.—End view of a log sawn by the live sawing method.
(M 148 327)

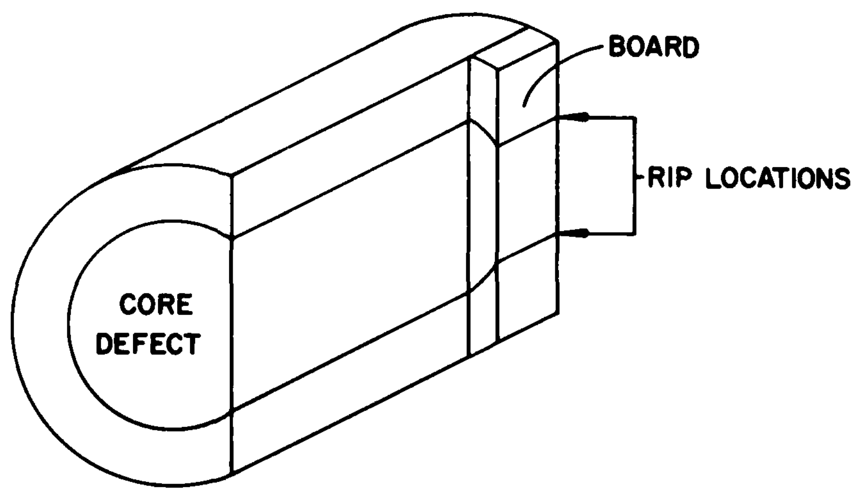

Figure 6.—Live-sawn lumber showing rip locations at intersection of the defective core with the outer board face.
(M 148 330)

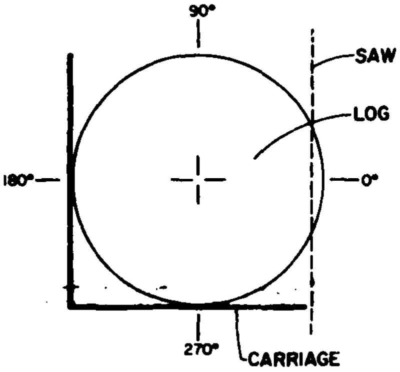

Figure 7.—The rotational position of the log and its faces with reference to the saw line.
(M 148 328)

to a log-frame saw with 1/8-inch kerf sawing 1-1/8-inch boards or with 3/16-inch kerf sawing 1-1/16-inch lumber.

The computer also kept track of the board foot volume (feet-board-measure, or fbm) in each log and at the completion of the sawing of each log in each rotational position calculated the percent volume yield of that sawing. This volume calculation was performed by first calculating the solid cubic foot volume of the truncated cone that represented the log prior to sawing. The log yield in board feet (fbm) was then converted to solid cubic feet of lumber by dividing the number of board feet by 12; this resultant value for solid cubic feet of lumber was divided by the solid cubic feet in the original log to determine the percent volume yield. It should be noted that this percent volume yield is really a measure of conversion efficiency of the sawing process and was *not* calculated with respect to any particular log rule for scaling logs to predict yield. These percent volume yield values are reported in the tables of results along with the value yields. Because of the set mechanical sawing patterns used in the quadrant, cant, and live sawing methods, the volume yield for any size log within each of these three methods will be identical although there are differences between the methods. Because of the judgments involved in them, the decision and the live rip sawing methods can, and sometimes do, result in different volume yields for different sawings of the same-sized log. When this occurs, the appropriate range of volumes is reported in the tabular results.

Grading and Pricing

In all the above sawing methods, the grading was done by the computer using the FPL computer grading program as modified for an IBM 370-165 computer. For comparative purposes it is desirable to use one price structure through a series of studies, yet it is also desirable to use relatively current prices in order to give a study credibility. The results of the current study are based on May 1978 Appalachian Red Oak prices on a board-foot basis: First and seconds (FAS) - $0.470; FAS One Face (1F) = $0.460; One Common (1C) - $0.390; Two Common (2C) - $0.205. All lower grades (mainly the defective heart center or core defect) were lumped together and assigned an arbitrary value of $0.085 per board foot.

Results

The raw data for 1-, 4-, 6-, and 8-inch core defects show the B, M, and W dollar values from the 12 rotational positions actually evaluated by the computer (tables 1-4). Knots were originally located at random, and that same knot configuration was then used for quadrant, cant, decision, live, and live rip sawings and, in addition, for live and live rip for 1/4-inch kerf sawings (tables 2-4). This means that if the random set of knots happened to be a good or bad configuration it was nevertheless applied identically to each sawing method and hence did not help or hurt any one sawing method with respect to the other methods. For each combination of log diameter and knot number, a new set of random knot locations was generated so that for 1-inch core defects (table 1), 16 different random knot patterns were generated and the same patterns were used for 4- and 6-inch core defects (tables 2 and 3). For 8-inch core defects (table 4), only the 14 appropriate random knot patterns were used because the 10-inch logs were omitted. Thus the study was conducted on 16 different random knot configurations. Each of the 12 sawing positions for any one simulated log was on the identical knot pattern, the whole knot pattern being rotated together by 15° increments in the same manner as a log could be rolled on the saw carriage. The substantial differences between the B and the W rotational positions for each log emphasize the value of computer simulation.

Because quadrant sawing was a rather consistent performer, data for all other sawing methods were expressed as percentages of the like volumes or values for quadrant-sawn logs (i.e., B as a percent of quadrant-sawn B, M as a percent of quadrant-sawn M, etc.) (tables 5-8). To better understand the average performance of the sawing methods, the mean values from tables 1-4 are summarized in tables 9-12. Ranges of performance exhibited by the various rotational positions are depicted as the difference in dollar value between the B and W rotational position expressed as a percent of W (tables 13-17).

To summarize the data further, the 15- and 30-knot mean values were averaged within each final subdivision of core defect, log size, and sawing method to yield both an average dollar value and a percent of quadrant-sawn log value for each such subdivision (tables 18-23) (figs. 8-13). The different methods of weighting a common data base affect percentages (table 24). Table 25 shows data obtained by averaging values for 1- and 4-inch core defects, omitting data for the larger core defects.

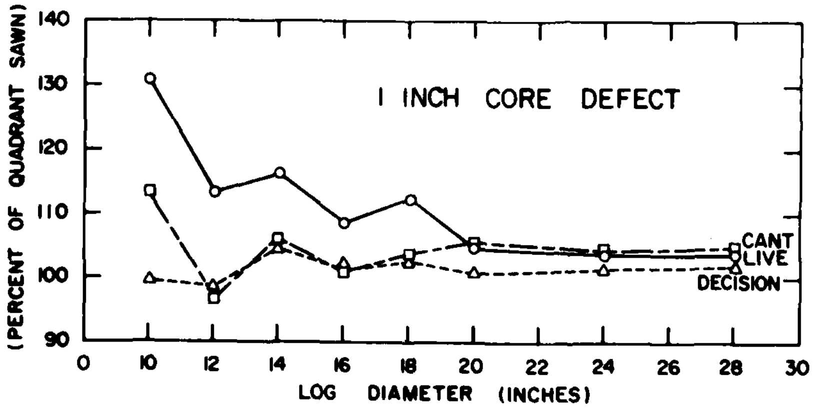

Figure 8.—Lumber values for three sawing methods, as percentages of values from quadrant-sawn logs with a 1-inch core defect.
(M 148 310)

Discussion

Sawing Methods

Perhaps the most surprising result is that the decisionmaking sawing method, which simulates the decisions of a skilled sawyer, does not perform any better than the purely mechanical methods of sawing a log. In fact, on the average, it performs slightly poorer than the other 4-sided sawing methods (tables 23 and 24). While this deficiency in performance is only 1 or 2 percent and can hardly be considered of high significance, it certainly can be said that decision sawing did *not* outperform the other sawing methods. What this seems to imply is that always turning to the best face of a log and sawing until the grade drops is not the best way to saw a hardwood log. A balanced method of sawing around the central core defects (such as quadrant sawing) seems to perform as well as, or slightly better than, a decisionmaking process. If the core defect had been offcenter, the decision sawing would probably have outperformed quadrant sawing but, until offcenter studies are performed, such a statement is only conjecture.

Live sawing and the three methods of 4-sided sawing all averaged within a percent or two of each other in value of lumber sawn (tables 23 and 24). Live sawing followed by reripping for grade, however, averaged about 7 percent higher in value than the 4-sided methods. Such gross averages hide some very interesting details. For example, live sawing tends to perform better on higher quality logs. Live sawing relative to quadrant sawing performs better on 15-knot logs than on 30-knot logs 80 percent of the time (tables 5-8,M). The margin of superiority of live sawing progressively declines in going from a 1-inch to an 8-inch core defect (tables 18-21) (figs. 8-11). For the 6- and 8-inch core defects, it performs better as the log size increases (figs. 10 and 11). It displays a reverse trend for the 1-inch core defect (fig. 8) and, following neither trend, tends to peak at the 18-inch log diameter for the 4-inch core logs in a manner similar to live rip sawing. The overall performance of live sawing is increased if only the 1- and 4-inch core defects are considered, omitting the logs with larger defects (table 25) (fig. 13). In such logs, live sawing averaged 8 percent better than quadrant sawing.

While both live and live rip sawing perform poorly on small logs with large core defects (tables 7 and 8) (figs. 10 and 11), live rip does not always follow the trend of live sawing to do relatively better in high-quality logs. For 1-inch core defects, the live sawing methods are identical to each other in value (table 5), and are better in the 15-knot than in the 30-knot logs; but for 4-, 6-, and 8-inch core defects (tables 6-8) live rip is relatively better in 30-knot than in 15-knot logs 74 percent of the time and for the 6-inch core defects (table 7), 100 percent of the time. Except for 1-inch core defect logs (fig. 8), where it is identical to live, live rip tends to peak at 18-inch logs (figs. 9-12) although for the 4-inch core defect there is a double peak (fig. 9) (table 19) with the peak for 12-inch logs being a fraction of a percent higher in relative value than the peak for 18-inch ones. Live rip does rather well when only 1-inch and 4-inch core defects are considered (table 25) (fig. 13), averaging 11 percent better than quadrant sawing.

Even though it showed erratic performance in this study, cant sawing should be given serious consideration because of its low production cost. It is hoped that future study will lead to a method for more nearly optimum cant-size selection. When such a selection system is available, cant sawing will undoubtedly perform better than it did in this study. Here, the arbitrary selection of [(D/2) - 2] for cant size was probably not the best for certain combinations of log size and core defect size. Because in smaller logs the cant method is sometimes the best and sometimes the worst sawing method, it seems desirable in the future to explore its performance on logs down to 8-inch diameter, in the hope that proper cant size selection can make it an outstanding performer on small logs. In small logs, cant sawing shows a slight superiority over quadrant and decision sawing when only 1- and 4-inch core defects are considered (table 25) (fig. 13), but it is still not as good as the live sawing methods. While some of the other methods also showed erratic performance on small logs, there does not seem to be a simple way to improve their performance (at least within the framework of uniform thickness of boards). All sawing methods could undoubtedly be improved by an optimum mix of different board thicknesses, but such an improvement is dependent on a more comprehensive theory of log sawing plus more adequate data on probable defect patterns in real logs.

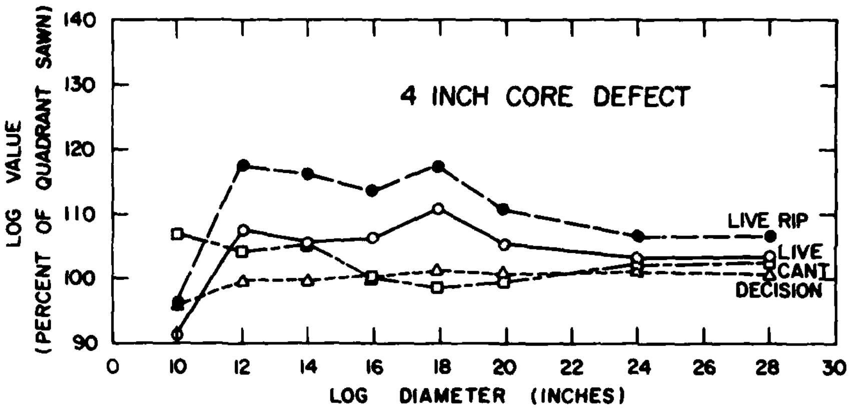

Figure 9.—Lumber values for four sawing methods as percentages of values from quadrant-sawn logs with a 4-inch-diameter core defect.

(M 148 311)

Orientation of Initial Cut

It seems that the most important decision the sawyer usually makes is the rotational position of the log on the carriage for the first cut. Analyses possible so far seem to support the old rule of thumb "corner the major defects" (i.e., place them near the edges of the sawing faces) for the 4-sided sawing methods. For the live sawing methods a rule of thumb is not as well established, but for a vertical cutting saw it often seems best to place the major defect clusters straight up or straight down if this is possible. This rule cannot be followed blindly, however, as there are numerous instances when placing the major defects at 30° and even at 90° to the vertical orientation has produced the optimum value yield.

Rotational position was important in this study for all sawing methods (tables 13-17) but particularly important for live sawing with an overall average of nearly 16 percent difference between the best and worst initial placement of the log on the carriage. Actual percentages range from a low of 0.4 percent up to a high of

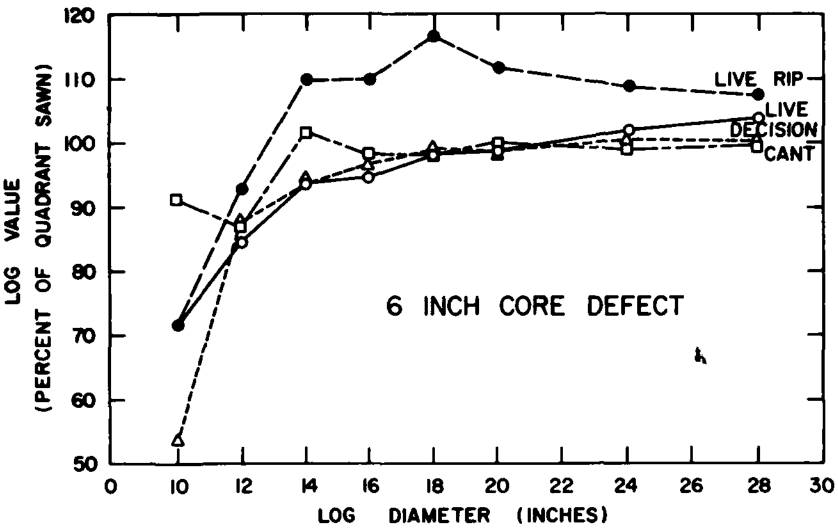

Figure 10.—Lumber values for four sawing methods as percentages of values from quadrant-sawn logs with a 6-inch-diameter core defect.
(M 148 312)

62.1 percent with an average of 11 percent and with over 13 percent of the individual values being above 20 percent (tables 13-16). On a percentage basis, orientation of the initial cut was especially important for the smaller logs.

Because of its potential importance this subject needs considerable additional study to develop better rules for live sawing.

Interactions and Weighting Systems

A review of the bottom of all tables that show means as a percent of a quadrant-sawn log reveals that noticeably different values appear for the same sawing methods. These are not computational or rounding errors but rather a result of following different calculational pathways that give a relatively greater or lesser importance to some factor such as log size, defect size, or dollar value. The differences resulting from these different weighting systems suggest that various important interactions may exist.

The fact that weighting by dollar value yields a slightly different percent-of-quadrant-sawn figure than does giving each log size an equal weight (table 24) suggests there may be an interaction between log size and sawing method (tables 18-21) (figs. 8-11). Above 20 inches in diameter there is not a great deal of variation between the sawing methods for any of the core defect sizes, although live rip seems to average about 7 percent higher than the other methods (tables 19-21) (figs. 9-11). At 16- and 18-inch diameters, live rip ranges from 5 to 17 percent better than quadrant sawing and shows the previously mentioned peak at 18 inches where it is 13.9 percent better than quadrant when values for all four core defect sizes are averaged (table 23) (fig. 12).

In the smaller sized logs (10, 12, and 14-in.) results are somewhat erratic and seem to indicate a three-way interaction between log size, core defect size, and sawing method. For example, live sawing ranges from 30.9 percent above quadrant to 28.5 percent below for 10-inch logs but remains relatively constant in 28-inch logs in going from 1-inch to 6-inch core defects (tables 18-20) (figs. 8-10). In 10-inch logs this same core size differential (1 to 6 in.) causes decision sawing values to drop from about equal to (i.e., 99.6 percent of) quadrant to 46.3 percent below quadrant (tables 18-20) (figs. 8-10). While not quite as spectacular, there are still some rather varied performances on 12- and 14-inch logs. Although some of this variation can be explained in the small logs with large core defects (cull logs that do not saw well by live sawing methods) on the basis of defect geometry, it seems that a more detailed study of small logs will be required to understand the various factors influencing the value yield. On the basis of the current investigation, however, it seems that small logs without excessive core defects should be live sawn followed by reripping for grade (where such reripping is appropriate), but small logs with an excessive amount of core defect should be sawed by some type of 4-sided method.

Live sawing does both its best and its worst in small logs—best when there is a small core defect (table 18) (fig. 8) and worst when there is a large core defect (tables 20 and 21) (figs. 10 and 11). Even live rip does not do too well in small logs with large core defects. If the central core defect is assumed to be rot, then 14-inch and smaller logs with an 8-inch core defect and 12-inch and smaller logs with a 6-inch core defect all have a cull factor greater than 50 percent by the squared defect rule. Because these are exactly the logs that do not saw out very well by live rip, it might be a good policy not to use it on small logs with a central rot column with a cull factor greater than 50 percent. If this central core defect is assumed to be made up of sound defects rather than rot, then the situation is quite different. The \$85/Mfbm assigned to this material is really a compromise value between \$0 for decayed wood and the \$160 to \$170 or more that sound oak pallet lumber might bring. Such a compromise in definition and pricing of the core defect is, of course, not completely fair to either possibility and it is not known whether this compromise biased the study for or against any particular sawing method. In larger logs, the relative value of this defective material is small and the exact pricing procedure probably unimportant. In small logs with a large core defect, however, the defective material is relatively more important and a full understanding of small-log sawing will require the modeling of both sound and unsound core defects with appropriate values for the low-grade lumber produced by each.

The summary values (table 24) deserve special consideration by anyone who wishes to evaluate the overall impact on a sawmill of any change in sawing practice. The weighting system used influences the percent advantage of one system over another. The equal weighting for each log size shows what the advantage of one system over another would be if the same log volume were sawn for each diameter class (a condition unlikely to occur in a real-life sawmill). The weighting by dollar value shows the relationship that would exist if an equal number of logs were sawn within each diameter class (again an unlikely occurence in real life). A sawmiller wishing to evaluate the impact of some change on his own production (for example, changing from 4-sided sawing to live rip) would need to know the distribution of his probable log mix by size and defect type, and apply the appropriate weighting to each subclassification to sum up these weighted values and arrive at an overall answer for his production.

Gains Due to Thinner Kerf

Sawmillers for years have argued over the exact benefits (or lack thereof) of going to a slightly thinner kerf. If one considers only the advantage of the thickness gained, then going from a 3/8-inch kerf to a 1/4-inch kerf should increase the volume conversion efficiency by 10 percent for 1-inch boards[(1.3750-1.2500)/1.2500 = 10 pct]. In the case of live sawing, the average volume yield gain in going from a 3/8-inch to a 1/4-inch kerf was 10.6 percent (tables 2-4) [(73.2-66.2)/66.2] and 10.9 percent (tables 6-8) [(119.9-108.1)/108.1]. The slight difference is due to the fact that one is weighted according to conversion efficiency and the other is weighted according to percent of a quadrant-sawn log. At least to a first approximation this seems to confirm the 10 percent theoretical figure. There seems to be little to be gained at this time by arguing whether the extra fractional part of a percentage unit is just an expected statistical variation or represents a small contribution from gained width or length in side-cut boards. Perhaps more definitive studies in the future can answer that question.

Glib statements about value gain due to thinner kerf are not so easy to make in a simulation study of this type. In this investigation, the live-sawn logs were assumed to be kerf centered (i.e., the central saw kerf splits the log in half longitudinally). Because this was done with mathematical precision, and because the central cylindrical core defect was also defined with mathematical precision, the exact penetration of the defect into the third or fourth board from the pith was determined by the kerf thickness plus the board thickness.

In the case of the 8-inch core defect, this becomes very critical for the fourth board outward from the pith. With 3/8-inch kerf, the defect does not even touch the fourth board outward whereas with 1/4-inch kerf the defect penetrates the inner face of the board 1/8 inch and produces a defect approximately 2 inches wide (i.e., 1.98 in.) all down the middle of the board. In large logs this degrade is more than compensated for by more and/or larger boards at outer levels, but for 12-inch logs there are no outer full-length boards beyond the fourth, the fifth being a very narrow board approximately 9 feet long. This means that the degrade of the fourth board outward from the pith can be enough to lower the value of a 12-inch log with

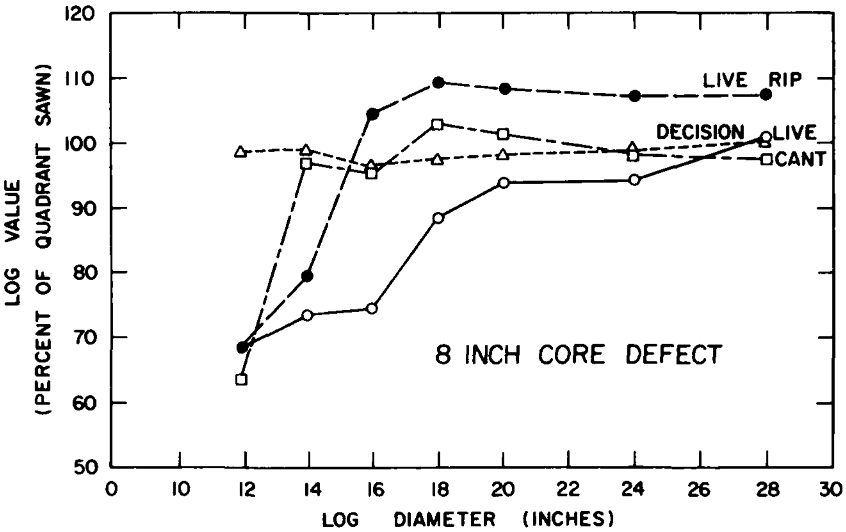

Figure 11.—Lumber values for four sawing methods as percentages of values from quadrant-sawn logs with an 8-inch-diameter core defect.
(M 148 313)

an 8-inch core defect to a lower value for 1/4-inch kerf than for 3/8. That such bizarre results can occasionally occur is shown by the 15-knot 12-inch log (tables 2 and 3) resulting from live sawing and the 30-knot 12-inch log (table 4). Such data can, of course, be misleading. On the average, the value yield of the 1/4-inch kerf sawings exceeded that of the 3/8-inch kerf sawings by 9.42 percent (tables 2, 3, and 4). In all probability, if the saw cuts were referenced with respect to the outside of the log rather than the center of the log, the bizarre results mentioned above would seldom, if ever, occur, but a positive statement to that effect must await further study. In the meantime it is only safe to say that, despite occasional bizarre results for logs with large defective cores, the average increase in lumber value due to narrower kerf is approximately equal to the gain in volume. It is hoped that further study will succeed in specifying sawing conditions that will allow the gain in value to exceed the gain in volume, but at the present this is still only a hope.

While a log-frame saw can cut somewhat thinner, for conditions in the United States, it seems best to assume a kerf no thinner than 5/32 inch (0.156). The accuracy, however, is so good that 1/16-inch oversize would probably be adequate. Such a combination would be approximately the equivalent of a 3/16-inch (0.188) kerf allowance rather than the 1/4-inch allowance made above. Theoretically, cutting 1-inch boards, such a kerf should yield 18 percent more lumber than a kerf allowance of 5/16 + 1/8-inch oversize (i.e. = 0.438 in. total). If the value yield closely followed this volume yield, then a switch from 4-sided sawing on a circular saw with a 3/8-inch (0.375) kerf allowance to a sash gang plus reripping should yield approximately 26 percent more value (7 pct for live rip plus 18 pct for kerf accuracy [1.07 × 1.18 = 1.2626] savings) than was obtained on the circular saw.

Volume versus Value Yield

When a particular sawing method yields a value different than some other method, the question arises as to whether this was due to a volume difference or a grade difference. Of the 4-sided methods, cant sawing averages 2.4 percent higher in volume but 0.5 percent lower in value while decision sawing averages 0.9 percent lower in volume and 2.4 percent lower in value than quadrant sawing (table 22). These small percentages are probably of little, if any, significance as variations nearly as large can be caused by different weighting systems (compare percent quadrant averages in table 22 with those in tables 23 and 24). The volume advantage of 7.9 percent for live sawing did not support a like value advantage but rather a 1 percent disadvantage. Live sawing results confirm that it performs rather poorly on large core defects, especially in small logs. In these low-grade and cull logs, live sawing must be producing low-grade lumber because its value yield falls so far short of its volume advantage. While

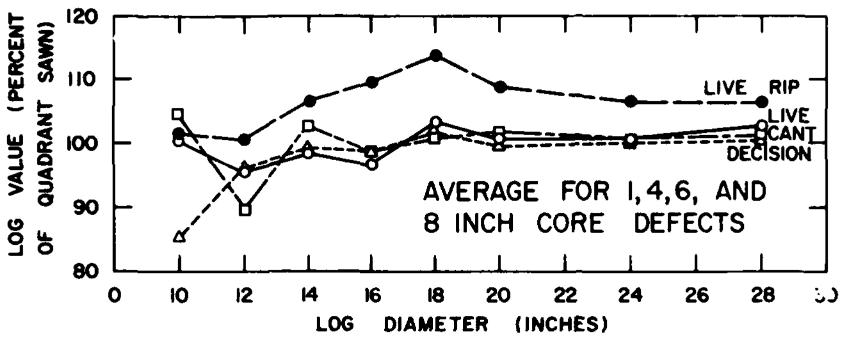

Figure 12.—Average lumber values for four sawing methods as percentages of values from quadrant-sawn logs of 1-, 4-, 6-, and 8-inch-diameter core defects.
(M 148 314)

live rip approximates its 6.6 percent volume advantage with a 6.1 percent value advantage (table 22), this is probably just a statistical accident: live sawing approximates its 7.9 percent volume advantage (table 22) with an 8.1 value advantage (table 25) while live rip exceeds its 6.6 percent volume advantage (table 22) with an 11.2 value advantage (table 25). Because a recent mill study[4] showed that a majority of logs had core defects ranging from 1- to 4-inches, table 25 has been limited to such logs. In these logs, live sawing methods perform much better in grade production than they did with the larger core defects. Thus, unlike a volume increase due to kerf reduction where value at least approximates volume change, a volume change brought about by changing the sawing method gives no assurance that a like change in value will occur. The value change, if any, will largely depend on how the sawing method interacts with the defect pattern to produce the various grades of lumber.

[4] Richards, D. B., and Newman, J. A. 1979. Value yield from medium- and low-grade red oak logs. Unpublished file report. Forestry Dep., University of Ky., Lexington, Ky.

Confirmation in Sawmill Studies

Because this study is based on simulated rather than real logs, it is a matter of considerable importance to see if similar results are obtainable in a real-life sawmill. The work of Peter (*18*) on yellow-poplar (*Liriodendron tulipifera*) indicates that live sawing often exceeds 4-sided sawing in value, but exact comparison with the present work is difficult because yellow-poplar grades are quite different from standard grades. The work at the Canadian Eastern Forest Products Laboratory on hard maple (*Acer saccharum*) is of special interest (*17, 20*). Because they give no detailed description of the extent of heart defects, it is difficult to compare their work to specific core defect sizes in this study, but it is still of considerable interest that their best logs (F1,~17 in. in diameter) gave live sawing a 13 percent value advantage over 4-sided grade sawing, that their medium-quality logs ("high line" F2, ~14 in. in diameter) gave live sawing a 6 percent and live rip a 54 percent value advantage over 4-sided grade sawing, and that their poorer logs (F3, ~11in. in diameter) gave 4-sided grade sawing a 6 percent value advantage over live sawing but live rip a 24 percent advantage over 4-sided grade sawing. While their values are not identical with the current study (and their 54 percent advantage for live rip is surprisingly high), their figures still support the poorer showing of live sawing as the log quality declines, and the need to rerip the live-sawn boards for grade to gain the true potential of live sawing.

A sawmill study on high-quality red oak logs (*26*) in general confirms the current computer study by giving a value advantage of 8.8 percent for live sawing and 14.1 percent for live rerip over 4-sided grade sawing for 18-inch logs. While not identical, these are somewhat similar to the 18-inch value advantages of 3.1 percent for live sawing and 13.9 percent for live rip in the current computer study (table 23) and very similar to the values (table 25) of 8.1 percent for live sawing and 11.2 percent for live rip. A second sawmill study on smaller sized medium- to low-quality red oak logs is currently underway. Although still incomplete, this second sawmill study seems to be giving at least general support to the computer study, with an 8 percent advantage for live sawing and a 16 percent advantage for live rip over corresponding grade sawing.

Because the sawmill studies often indicate a somewhat greater advantage for live sawing than does the current computer study, this fact deserves some attention. The current study was designed to gain information rather than to promote some particular sawing method. Because it was suspected that live sawing might have trouble with large core defects, these large defective cores were included to test that idea. The sawmill studies probably included few if any logs with 6- and 8-inch cores that yielded no clear cuttings. When these large defective cores are eliminated from the data and only the 1- and 4-inch defective cores used, the live sawing methods perform more nearly in accord with the sawmill studies (table 25) (fig. 13). Another reason for the difference is that the reripping procedure used in the computer study was not an optimum one and careful reripping in a closely controlled sawmill study is probably much closer to optimum than was the fairly mechanical procedure used in the computer study.

As the evidence is accumulating that live sawing (at least if followed by skillful reripping) yields more value from most hardwood than does 4-sided grade sawing, a question of considerable importance is why sawmills in the United States have failed to discover this by empirical studies. There are probably three reasons for this failure: there is a tendency to think of live sawing as a low-cost method incapable of producing high grade and hence only useful on small low-grade logs—exactly those logs where it may perform rather poorly; there is a tendency for sawmills to evaluate performance based on dollars per thousand feet of output, a practice which completely ignores the higher gross-volume yield per log from live sawing; perhaps most importantly, live sawing is very dependent on skillful edging and ripping for grade. These skills are often not available in the typical hardwood mill and, even if they are available, one edgerman probably cannot keep up with a high volume of live-sawn boards. For live sawing to attain its potential there must be a reordering of priorities in a sawmill. The edgerman becomes the most important worker on the floor of the mill and should be trained and paid accordingly. For any very high production operation, there should probably be two edgers and two well-trained edgermen.

Several studies have suggested that live sawing may produce more profit than grade sawing but largely because of higher production rates (and hence lower costs) rather than because of a much higher value of lumber produced from a log (*10, 11, 15*). In fact, several of these studies indicate certain conditions where live sawing may produce less lumber value than grade sawing. These studies in general allowed the sawmill to do its edging in the conventional way using their regular edgerman. Thus these studies may offer evidence in support of the third reason above for the failure of sawmills to discover the advantage of live sawing. If a hardwood sawmill edges in the conventional manner, it usually edges too severely and loses considerable value. Because only some boards are edged by the edgerman in grade sawing—whereas all boards are edged by the edgerman in live sawing—there is likely to be more loss in edging in live sawing than in grade sawing in a conventional mill *unless there is a complete retraining of* the edgerman. The fact that live sawing is hurt by poor edging practices and helped more by good edging practices than is grade sawing may explain some of the low-valued yields for live sawing in some past mill studies. In general, however, the literature indicates that live sawing hardwood logs yields more value than does 4-sided grade sawing (*2-7, 10, 12, 17, 18, 20-23, 25, 27, 28).*

Production Costs and Lumber Prices

While this study has been concerned with value, it is not, strictly speaking, an economic study as there has been no evaluation of production cost. At least for small- and medium-sized logs, live sawing will have a somewhat lower production cost at the headrig even for a conventional mill (*3, 10, 11, 15, 19*) and considerably lower cost than 4-sided sawing if a log-frame saw is used. Edging costs will probably be higher for live sawing than for 4-sided sawing because all boards must be edged at the edger. Just what the balance between these opposing factors will be must await production studies in various types of mill setups, but it seems likely that live sawing will prove to be a considerably lower cost overall production method in a properly designed and operated mill than is 4-sided sawing; this will be especially true in an automated log-frame saw mill.

The assumption throughout this study is that standard prices will prevail for all sawing methods. There are certain conditions where this assumption may not be true. In species where sapwood and heartwood are priced differently, live sawing—by mixing these two in most boards—may cause problems that will either lower the average price or else entail an excessive amount of reripping. Species such as maple and sweetgum (i.e., sapgum plus redgum) may fall into such a class.

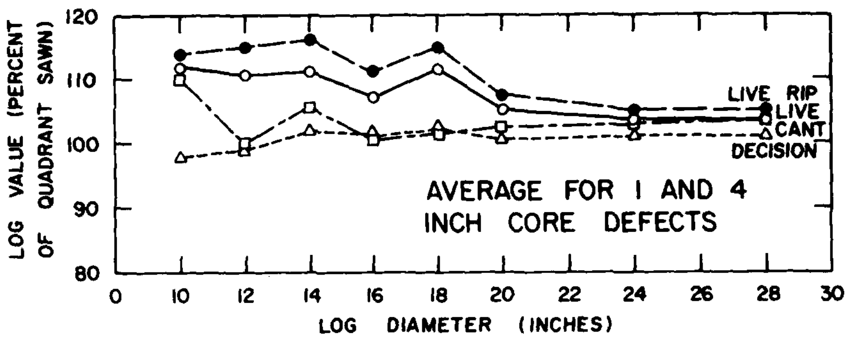

Figure 13.—Average lumber values for four sawing methods as percentages of values from quadrant-sawn logs of 1- and 4-inch-diameter core defects.

(M 148 315)

On the other hand, species in which a ray fleck, ribbon stripe, or comb grain is desirable may at times pay a rather substantial premium for these grain patterns. Ring-porous species (especially oak) and those with an interlocked grain (and hence a potential for ribbon stripe) fall into this classification. While live sawing is not designed to produce the maximum amount of radial (i. e., quartered) grain, it does produce a great deal more of it than does 4-sided sawing (*17*) which produces mainly tangential (i.e., flat) grain. For such species (particularly oak, for which there is a premium market for comb grain stock) there might be a price advantage to live sawing. Such consideration would have to be evaluated for each species and each market area. It should also be noted that live-sawn lumber may offer some problems in a rough mill if the workers are not used to handling it (19).

Summary and Conclusions

Hardwood sawlogs with various-sized core defects and with two different quantities of hidden and surface knots were simulated on an electronic computer as truncated cones with standard log taper. These simulated logs were sawed by simulation using live sawing and various 4-sided sawing methods including a decision method that simulates the decisions of a skilled sawyer. Except for some erratic behavior in 10- and 12-inch logs, the 4-sided sawing methods (quadrant, cant, and decision) tended to yield similar values. Live sawing was moderately effective in good logs but inferior to the 4-sided methods in small logs with large core defects. Live sawing followed by reripping for grade (live rip) outperformed the 4-sided sawing methods by an average of 7 percent and for the 16- and 18-inch size classes in average or better logs outperformed them by about 16 percent. The rotational position on the carriage for the first cut was important for all sawing methods with the best position outperforming the worst by as much as 62 percent and averaging 11 percent. Reducing the saw kerf from 3/8 to 1/4 inch increased the volume yield by slightly over 10 percent and, despite a few bizarre but explainable counterinstances, increased the value yield on the average by nearly the same amount.

While sweeping generalizations will have to await additional supporting studies in real sawmills, the evidence thus far indicates there is considerable value to be gained by live sawing hardwood logs that do not have an excessive amount of heart rot or other large core defects. To gain the full potential of live sawing, the central wide boards must be skillfully reripped for grade. Failure to perform well at this reripping task can lead to a disappointing value yield from live sawing.

Log-Frame Headsaws

A decision to live saw would allow the use of a log-frame headsaw. The advantages of a log-frame over a conventional heading include a high production at a low cost in both money and man-hours, thin kerf, good accuracy in cutting, relatively modest demands for skill in the head sawyer, the unique ability to follow the curve in a log with a moderate amount of sweep, and a materials flow system that is well adapted to automation. Its disadvantages are high initial cost, need for a heavy permanent foundation, demand for a large volume of logs to keep it busy, lack of flexibility in sawing pattern and hence the necessity for careful log sorting, the high demand it places on the edging operation with respect to both volume output and high technical skill in reripping for grade, and the inability to handle the very large diameter logs that still show up in small numbers at hardwood sawmills. While no general recommendations can be made at this time, it does seem that if the cost of logs and labor continues to rise as it has in the past, the use of a log-frame saw on hardwoods will probably look more and more attractive. The crucial question is the availability of a sufficient supply of hardwood timber within reasonable hauling distance of the mill. If such a supply is available, then serious consideration should be given to the use of a log-frame saw on hardwoods.

Table 1.—Volume[1] and value yield of 12-foot hardwood logs, with a centrally located 1-inch-diameter cylindrical core defect, sawn with a 3/8-inch kerf into 1-inch boards

Diameter	Knots per log	Rotational position[3]	Quadrant Volume	Quadrant Value	Cant Volume	Cant Value	Decision Volume	Decision Value	Live[2] Volume	Live[2] Value
In.			%	$/log	%	$/log	%	$/log	%	$/log
10	15	B		15.59		16.44		15.07		19.17
		M	54.1	13.81	56.1	15.41	53.5	13.76	61.4	18.48
		W		12.49		13.50		12.11		17.46
	30	B		9.25		10.46		8.91		11.28
		M	54.1	7.92	56.1	9.21	53.5	[illegible].87	61.4	9.96
		W		6.67		7.64		7.09		7.96
12	15	B		31.30		28.39		28.71		34.92
		M	57.5	29.71	59.2	27.39	57.1	28.01	64.1	33.66
		W		28.34		26.17		27.19		31.98
	30	B		21.73		23.38		23.01		26.87
		M	57.5	20.52	59.2	21.71	57.1	21.52	64.1	23.25
		W		17.82		20.28		19.93		19.08
14	15	B		39.77		41.39	60.8	42.29		47.27
		M	61.4	38.15	63.1	39.65	60.8	39.77	66.0	45.70
		W		35.06		36.99	60.6	37.78		44.78
	30	B		33.36		36.02	60.8	35.00		37.52
		M	61.4	30.89	63.1	33.53	60.8	32.40	66.0	34.52
		W		29.35		31.92	60.5	30.42		30.56
16	15	B		56.46		55.58	62.1	55.20		62.45
		M	62.1	53.82	62.3	53.90	61.9	53.90	66.6	60.85
		W		52.53		52.14	61.6	52.07		59.64
	30	B		48.58		50.31	62.1	52.53		52.50
		M	62.1	47.08	62.3	48.00	61.9	48.19	66.6	48.69
		W		45.48		46.42	61.0	45.20		42.96
18	15	B		69.22		73.64	60.4	72.57		79.40
		M	60.4	68.04	63.0	70.99	59.7	70.28	66.0	77.58
		W		65.98		68.95	59.0	65.00		75.55
	30	B		61.70		62.61	60.4	60.42		68.53
		M	60.4	58.68	63.0	60.78	59.7	59.68	66.0	64.63
		W		56.38		57.21	59.0	58.98		60.39
20	15	B		92.27		96.51	63.3	92.59		101.94
		M	63.7	89.83	65.3	94.87	62.8	89.43	67.7	97.54
		W		87.58		92.73	61.9	87.14		94.39
	30	B		83.20		87.11	63.5	84.94		85.37
		M	63.7	79.40	65.3	83.73	63.2	81.09	67.7	79.90
		W		75.54		80.72	62.2	75.94		73.42
24	15	B		137.37		142.93	65.0	138.46		148.29
		M	65.1	135.67	66.4	140.51	64.6	135.97	68.5	144.38
		W		133.93		136.81	63.8	132.29		141.73
	30	B		124.62		130.29	65.0	127.12		128.55
		M	65.1	121.32	66.4	126.82	54.0	124.08	68.5	122.07
		W		118.50		123.36	62.5	121.45		112.11
28	15	B		193.95		200.52	65.9	194.42		203.87
		M	66.4	188.05	67.2	196.83	64.5	188.86	69.2	200.00
		W		185.41		193.48	63.0	184.59		195.41
	30	B		177.50		187.59	65.9	183.01		190.57
		M	66.4	174.10	67.2	181.87	64.8	179.10	69.2	175.22
		W		170.65		175.53	63.0	174.45		164.95
Mean of means			61.3	72.30	62.8	75.33	60.6	73.37	66.2	77.28

[1]Expressed as percent of solid cubic volume of log.
[2]Live rip was omitted because all values were identical to live sawn values.
[3]B = Best, M = Mean, and W = Worst of the 12 rotational positions from 0° to 165° for the plane of the initial saw cut.

Table 2.—Volume[1] and value yield of 12-foot hardwood logs, with a centrally located 4-inch-diameter cylindrical core defect, sawn into 1-inch boards

Diameter	Knots per log	Rotational position[2]	3/8-inch kerf										1/4-inch kerf			
			Quadrant		Cant		Decision		Live		Live rip		Live		Live rip	
			Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value
In.			%	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%	$/log
10.0	15	B	54.1	13.78	56.1	15.07	53.5	12.79	61.4	11.76	61.4	12.52	70.1	15.17	69.0	16.77
		M	54.1	12.65	56.1	13.11	53.5	12.00	61.4	11.04	56.9	11.49	70.1	13.64	69.0	14.92
		W	54.1	11.89	56.1	11.74	53.5	10.91	61.4	10.05	54.2	10.61	70.1	11.98	69.0	13.58
	30	B	54.1	8.43	56.1	9.62	53.5	8.09	61.4	8.94	61.4	8.94	70.1	10.84	70.1	12.06
		M	54.1	7.66	56.1	8.59	53.5	7.47	61.4	7.52	58.1	8.02	70.1	9.48	69.3	10.73
		W	54.1	6.67	56.1	7.10	53.5	6.66	61.4	6.73	54.2	6.87	70.1	7.98	69.0	9.67
12.0	15	B	57.5	26.70	59.2	26.69	57.1	25.66	64.1	29.13	63.3	30.95	70.6	27.35	69.8	29.02
		M	57.5	25.36	59.2	25.87	57.1	24.70	64.1	28.21	63.3	30.21	70.6	26.57	69.8	28.56
		W	57.5	24.69	59.2	25.21	57.1	23.38	64.1	27.01	63.3	28.58	70.6	25.58	69.8	27.91
	30	B	57.5	20.81	59.2	22.75	57.1	21.08	64.1	22.43	63.7	25.50	70.6	22.50	70.2	25.57
		M	57.5	19.94	59.2	21.32	57.0	20.44	64.1	20.52	63.4	23.01	70.6	20.97	69.8	23.77
		W	57.5	17.82	59.2	20.23	56.9	19.72	64.1	16.95	63.3	20.69	70.6	17.92	69.8	20.99
14.0	15	B	61.4	38.75	63.1	38.34	60.8	36.74	66.0	44.78	66.0	45.04	71.6	47.57	71.6	49.09
		M	61.4	36.75	63.1	37.72	60.7	35.64	66.0	39.87	65.6	42.09	71.6	42.30	71.2	44.26
		W	61.4	34.46	63.1	36.39	60.5	34.37	66.0	34.84	65.4	37.98	71.6	37.97	71.0	41.12
	30	B	61.4	31.99	63.1	35.09	60.8	32.41	66.0	34.42	65.8	39.31	71.6	35.65	71.3	40.35
		M	61.4	30.51	63.1	33.15	60.8	31.41	66.0	31.17	65.5	36.10	71.6	32.68	71.0	37.70
		W	61.4	29.24	63.1	31.32	60.5	29.72	66.0	27.76	65.4	32.65	71.6	28.45	71.0	33.34
16.0	15	B	62.1	53.56	62.3	52.00	62.1	52.98	66.6	59.82	66.6	59.82	72.5	67.61	72.5	67.61
		M	62.1	51.66	62.3	50.96	61.9	51.02	66.6	57.32	66.5	58.37	72.5	64.46	72.4	65.92
		W	62.1	50.41	62.3	49.59	61.6	48.66	66.6	51.47	66.2	55.81	72.5	59.73	72.1	64.07
	30	B	62.1	46.45	62.3	47.76	62.1	48.29	66.6	50.91	66.4	55.33	72.5	57.91	72.3	62.74
		M	62.1	45.44	62.3	46.12	61.9	46.31	66.6	45.72	66.2	51.93	72.5	52.52	72.1	58.57
		W	62.1	43.35	62.3	44.98	61.0	43.07	66.6	42.96	66.2	49.61	72.5	48.69	72.1	54.56
18.0	15	B	60.4	67.69	63.0	66.59	60.4	69.53	66.0	78.12	66.0	78.22	74.2	88.35	74.2	88.35
		M	60.4	66.08	63.0	65.26	59.8	66.53	66.0	76.03	66.0	76.52	74.2	85.01	74.1	85.50
		W	60.4	64.46	63.0	63.00	59.0	64.06	66.0	72.47	65.7	75.55	74.2	79.64	73.8	79.65
	30	B	60.4	60.50	63.0	60.09	60.4	61.11	66.0	67.77	65.9	72.37	74.2	75.11	74.0	80.77
		M	60.4	58.23	63.0	57.70	59.8	59.18	66.0	61.80	65.7	69.15	74.2	68.30	73.9	76.36
		W	60.4	56.38	63.0	54.69	59.0	56.63	66.0	57.06	65.7	65.44	74.2	62.75	73.8	70.72
20.0	15	B	63.7	89.35	65.3	88.27	63.3	89.54	67.7	101.49	67.7	101.49	75.1	111.73	75.1	111.98
		M	63.7	87.54	65.3	86.34	62.8	86.71	67.7	96.64	67.5	96.87	75.0	107.25	74.8	107.50
		W	63.7	85.72	65.3	84.55	61.9	83.57	67.7	94.39	67.4	94.72	75.1	104.76	74.8	105.14
	30	B	63.7	82.73	65.3	81.79	63.5	84.34	67.7	85.37	67.5	91.26	75.1	94.17	74.9	101.56
		M	63.7	79.15	65.3	79.77	63.2	80.74	67.7	78.65	67.4	87.76	75.0	86.95	74.8	96.37
		W	63.7	75.35	65.3	76.88	62.2	75.94	67.7	73.42	67.4	83.30	75.1	78.47	74.8	89.43
24.0	15	B	65.1	135.25	66.4	139.18	65.0	135.75	68.5	146.09	68.5	146.66	75.4	159.13	75.4	159.39
		M	65.1	133.36	66.4	135.61	64.7	133.87	68.5	142.49	68.4	142.98	75.3	155.86	75.2	156.36
		W	65.1	131.61	66.4	133.11	63.8	129.55	68.5	139.20	68.3	140.05	75.4	151.15	75.1	151.61
	30	B	65.1	123.83	66.4	127.44	65.0	126.52	68.5	127.27	68.4	135.20	75.4	136.00	75.3	143.20
		M	65.1	120.83	66.4	123.97	64.1	122.99	68.5	119.92	68.3	128.03	75.3	131.28	75.2	139.05
		W	65.1	117.68	66.4	119.11	62.5	120.21	68.5	110.40	68.3	118.80	75.4	125.84	75.1	132.93
28.0	15	B	66.4	191.50	67.2	196.08	65.9	188.91	69.2	201.77	69.2	202.41	76.1	220.48	76.1	221.12
		M	66.4	186.68	67.2	191.25	64.6	185.09	69.2	197.83	69.1	199.20	76.1	215.01	76.0	216.45
		W	66.4	184.04	67.2	188.10	63.0	179.70	69.2	194.44	69.1	195.63	76.1	208.44	76.0	210.10
	30	B	66.4	177.50	67.2	183.99	65.9	183.01	69.2	186.24	69.1	188.93	76.1	198.24	76.1	207.71
		M	66.4	174.05	67.2	178.79	65.2	178.03	69.2	175.55	69.1	185.15	76.1	188.33	76.0	200.81
		W	66.4	170.65	67.2	173.31	63.0	174.45	69.2	165.85	69.1	181.87	76.1	180.13	76.0	194.97
Mean of means			61.3	70.99	62.8	72.22	60.7	71.38	66.2	74.39	65.4	77.93	73.2	81.29	72.8	85.18

[1]Expressed as percent of solid cubic volume of log
[2]B = Best, M = Mean, and W = Worst of the 12 rotational positions from 0° to 165° for the plan of the initial saw cut

Table 3.—Volume[1] and value yield of 12-foot hardwood logs, with a centrally located 6-inch-diameter cylindrical core defect, sawn into 1-inch boards

Diameter	Knots per log	Rotational position[2]	3/8-inch kerf										1/4-inch kerf			
			Quadrant		Cant		Decision		Live		Live rip		Live		Live rip	
			Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value
In.			%	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%	$/log
10.0	15	B	54.1	11.15	56.1	8.76	53.5	4.70	61.4	7.83	61.4	7.83	70.1	6.41	70.1	6.41
		M	54.1	10.01	56.1	8.61	53.5	4.56	61.4	6.71	61.4	6.71	70.1	6.41	70.1	6.41
		W	54.1	8.74	56.1	8.30	53.5	4.42	61.4	6.49	61.4	6.49	70.1	6.41	70.1	6.41
	30	B	54.1	7.68	56.1	8.30	53.5	4.70	61.4	6.49	61.4	6.49	70.1	6.41	70.1	6.41
		M	54.1	6.94	56.1	6.83	53.5	4.54	61.4	5.40	61.4	5.40	70.1	6.24	70.1	6.24
		W	54.1	6.21	56.1	5.12	53.5	4.42	61.4	4.75	61.4	4.75	70.1	5.91	70.1	5.91
12.0	15	B	57.5	24.58	59.2	19.60	57.1	20.63	64.1	21.29	62.9	22.68	70.6	19.53	70.2	20.62
		M	57.5	23.50	59.2	19.56	57.1	19.88	64.1	19.86	62.7	21.46	70.6	17.90	69.8	18.83
		W	57.5	23.16	59.2	19.52	57.1	18.49	64.1	18.06	62.6	19.71	70.6	15.97	69.8	17.05
	30	B	57.5	20.10	59.2	18.24	57.1	19.03	64.1	17.36	63.7	20.36	70.6	17.22	70.2	18.56
		M	57.5	18.76	59.2	17.09	57.1	16.98	64.1	15.72	62.9	17.68	70.6	15.90	69.9	16.98
		W	57.5	16.32	59.2	15.67	57.1	15.79	64.1	13.64	62.6	15.34	70.6	15.01	69.8	15.71
14.0	15	B	61.4	36.55	63.1	36.32	60.8	33.12	66.0	35.59	61.6	39.77	71.6	37.89	70.4	40.57
		M	61.4	35.07	63.1	35.23	60.8	31.29	66.0	33.01	61.6	37.88	71.6	33.44	70.4	38.59
		W	61.4	33.03	63.1	34.56	60.8	29.92	66.0	3.51	61.6	35.64	71.6	30.34	70.4	35.29
	30	B	61.4	29.98	63.1	32.97	60.8	30.48	66.0	31.88	63.6	36.03	71.6	30.66	70.7	36.18
		M	61.4	29.22	63.1	29.94	60.8	28.58	66.0	27.25	62.0	32.71	71.6	27.41	70.5	33.20
		W	61.4	27.92	63.1	28.34	60.8	27.60	66.0	24.37	61.6	29.74	71.6	25.06	70.4	30.47
16.0	15	B	62.1	51.12	62.3	48.45	62.1	49.83	66.6	48.58	63.2	55.09	72.5	56.62	71.6	64.27
		M	62.1	49.61	62.3	47.52	52.0	47.44	66.6	46.87	63.2	53.24	72.5	54.48	71.6	60.99
		W	62.1	48.37	62.3	46.82	61.6	45.81	66.6	44.93	63.2	51.46	72.5	52.40	71.6	55.00
	30	B	62.1	45.53	62.3	45.02	62.1	44.72	66.6	43.62	63.2	50.10	72.5	49.18	71.9	57.62
		M	62.1	43.35	62.3	43.60	62.0	41.88	66.6	40.88	63.2	48.89	72.5	47.44	71.6	55.50
		W	62.1	42.01	62.3	42.64	61.9	39.70	66.6	37.32	63.2	45.78	72.5	43.64	71.6	52.24
18.0	15	B	60.4	65.24	63.0	63.13	60.4	64.45	66.0	64.62	65.3	73.88	74.2	75.01	73.4	83.73
		M	60.4	64.35	63.0	61.28	60.4	62.73	66.0	62.66	65.3	71.88	74.2	71.32	73.4	80.23
		W	60.4	63.26	63.0	60.03	60.3	60.16	66.0	61.45	65.3	70.44	74.2	64.93	73.4	74.58
	30	B	60.4	57.88	63.0	57.28	60.4	58.99	66.0	57.69	65.3	68.79	74.2	64.73	73.4	76.36
		M	60.4	56.13	63.0	55.55	60.4	55.35	66.0	55.48	65.3	67.00	74.2	61.14	73.4	72.79
		W	60.4	53.71	63.0	53.0'	60.3	53.61	66.0	53.89	65.3	64.22	74.2	58.39	73.4	68.35
20.0	15	B	63.7	87.87	65.3	85.89	63.3	86.36	67.7	95.30	67.5	96.63	75.1	105.82	75.1	108.26
		M	63.7	85.48	65.3	83.89	63.2	82.82	67.7	86.67	67.2	93.92	75.0	98.53	74.7	104.42
		W	63.7	83.15	65.3	81.59	63.1	79.75	67.7	78.81	67.1	91.16	75.1	88.43	74.5	100.42
	30	B	63.7	81.30	65.3	80.31	63.5	80.27	67.7	75.56	67.2	89.44	75.1	90.47	74.8	98.30
		M	63.7	76.89	65.3	78.16	63.3	77.17	67.7	73.17	67.1	87.15	75.0	81.40	74.5	94.44
		W	63.7	72.58	65.3	76.88	63.2	75.33	67.7	67.26	67.1	81.53	75.1	74.77	74.5	90.74
24.0	15	B	65.1	133.12	66.4	130.68	65.0	131.73	68.5	144.29	68.5	144.72	75.4	158.93	75.4	158.93
		M	65.1	131.42	66.4	128.46	64.9	129.89	68.5	137.60	68.3	141.24	75.3	151.43	75.2	154.69
		W	65.1	129.73	66.4	126.33	64.7	127.48	68.5	130.67	68.2	138.05	75.4	145.21	75.0	151.30
	30	B	65.1	122.49	66.4	123.19	65.0	124.21	68.5	121.95	68.4	135.36	75.4	135.85	75.3	147.42
		M	65.1	119.96	66.4	119.50	64.7	121.50	68.5	117.87	68.2	130.81	75.3	129.74	75.1	144.16
		W	65.1	117.08	66.4	116.58	63.8	118.88	68.5	110.88	68.1	122.24	75.4	123.92	74.9	140.39
28.0	15	B	66.4	188.13	67.2	187.19	65.9	186.83	69.2	199.44	69.2	200.05	76.1	216.55	76.1	218.79
		M	66.4	185.10	67.2	183.84	65.0	182.51	69.2	195.38	68.7	197.17	76.1	212.29	76.0	214.39
		W	66.4	180.35	67.2	178.84	63.0	176.28	69.2	189.21	68.2	193.11	76.1	204.24	76.0	205.01
	30	B	66.4	176.90	67.2	177.39	65.9	179.08	69.2	191.52	69.2	191.52	76.1	195.10	76.1	210.00
		M	66.4	172.88	67.2	171.20	65.7	175.11	69.2	175.49	68.7	186.00	76.1	189.36	76.0	203.12
		W	66.4	168.79	67.2	166.32	65.3	172.93	69.2	165.85	68.1	181.51	76.1	184.01	75.9	194.05
Mean of means			61.3	69.23	62.8	68.14	60.9	67.64	66.2	68.75	64.8	74.95	73.2	75.28	72.6	81.56

[1]Expressed as percent of solid cubic volume of log
[2]B = Best, M = Mean, and W = Worst of the 12 rotational positions from 0° to 165° for the plan of the initial saw cut

Table 4.—Volume[1] and value yield of 12-foot hardwood logs, with a centrally located 8-inch-diameter cylindrical core defect, sawn into 1-inch boards

Diameter	Knots per log	Rotational position[2]	3/8-inch kerf										1/4-inch kerf			
			Quadrant		Cant		Decision		Live		Live rip		Live		Live rip	
			Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value	Volume	Value
In.			%	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%	$/log
12.0	15	B	57.5	18.12	59.2	13.75	57.1	16.91	64.1	12.22	64.1	12.22	70.6	13.43	70.6	13.43
		M	57.5	17.71	59.2	11.57	57.1	16.85	64.1	11.77	64.1	11.77	70.6	11.80	70.6	11.80
		W	57.5	17.63	59.2	10.48	57.1	16.84	64.1	11.24	64.1	11.24	70.6	9.91	70.6	9.91
	30	B	57.5	16.21	59.2	10.48	57.1	16.21	64.1	11.73	64.1	11.73	70.6	12.26	70.6	12.26
		M	57.5	15.38	59.2	9.54	57.1	15.84	64.1	10.86	64.1	10.86	70.6	10.65	70.6	10.65
		W	57.5	13.98	59.2	9.19	57.1	15.72	64.1	9.94	64.1	9.94	70.6	9.59	70.6	9.59
14.0	15	B	61.4	31.17	63.1	30.38	60.8	30.05	66.0	23.52	65.4	24.98	71.6	23.53	69.8	31.08
		M	61.4	30.27	63.1	29.10	60.8	29.51	66.0	22.03	64.9	23.74	71.6	22.90	69.8	31.05
		W	61.4	29.23	63.1	28.06	60.8	29.02	66.0	19.72	64.4	21.56	71.6	22.56	69.8	29.23
	30	B	61.4	28.45	63.1	28.64	60.8	28.77	66.0	21.95	65.4	23.52	71.6	22.64	70.4	25.80
		M	61.4	27.30	63.1	26.76	60.8	27.46	66.0	20.45	64.6	22.19	71.6	20.61	70.2	25.71
		W	61.4	26.06	63.1	23.89	60.8	26.54	66.0	16.40	63.4	19.71	71.6	17.93	69.8	23.52
16.0	15	B	62.1	45.81	62.3	44.59	62.0	43.75	66.6	34.45	64.1	47.89	72.5	42.09	71.4	53.44
		M	62.1	44.69	62.3	42.34	61.8	42.74	66.6	32.94	64.1	46.46	72.5	40.21	71.2	50.98
		W	62.1	43.34	62.3	39.79	61.6	41.13	66.6	30.55	64.1	43.47	72.5	37.87	71.2	49.64
	30	B	62.1	42.95	62.3	40.77	62.1	41.61	66.6	32.40	64.9	44.84	72.5	38.51	71.4	48.70
		M	62.1	40.47	62.3	38.90	61.9	39.48	66.6	30.85	64.3	42.84	72.5	36.88	71.3	47.59
		W	62.1	39.09	62.3	37.37	61.6	36.85	66.6	29.04	64.1	39.89	72.5	34.53	71.2	46.62
18.0	15	B	60.4	60.63	63.0	62.97	60.3	58.44	66.0	58.02	65.3	69.11	74.2	64.88	73.3	73.43
		M	60.4	59.23	63.0	61.09	60.2	57.63	66.0	53.35	64.4	64.03	74.2	59.61	73.1	71.69
		W	60.4	58.12	63.0	59.87	60.1	56.01	66.0	49.53	64.2	61.68	74.2	55.95	73.1	68.70
	30	B	60.4	55.53	63.0	57.28	60.4	54.35	66.0	51.40	64.8	63.23	74.2	57.84	73.3	69.37
		M	60.4	53.92	63.0	55.55	60.3	53.03	66.0	47.28	64.3	59.89	74.2	54.63	73.1	66.22
		W	60.4	51.88	63.0	53.01	60.1	51.81	66.0	43.53	64.2	56.60	74.2	51.81	73.1	62.51
20.0	15	B	63.7	82.29	65.3	82.83	63.2	80.00	67.7	85.10	67.1	93.49	75.1	90.07	74.3	100.93
		M	63.7	80.22	65.3	81.13	63.1	78.58	67.7	79.86	66.7	88.60	75.0	86.96	74.3	97.84
		W	63.7	77.73	65.3	79.67	63.0	77.29	67.7	75.89	66.2	86.14	75.1	83.44	74.2	95.21
	30	B	63.7	78.33	65.3	77.69	63.4	77.25	67.7	69.46	67.1	81.98	75.1	76.16	74.5	90.79
		M	63.7	74.71	65.3	76.12	63.2	73.87	67.7	65.76	66.4	79.56	75.0	73.34	74.2	88.83
		W	63.7	70.22	65.3	74.96	63.1	71.63	67.7	63.20	66.2	77.46	75.1	70.30	74.2	85.69
24.0	15	B	65.1	128.73	66.4	125.73	64.8	126.44	68.5	124.72	68.1	137.08	75.4	136.67	74.9	150.60
		M	65.1	127.09	66.4	123.96	64.7	124.42	68.5	121.50	67.6	135.06	75.3	132.15	74.8	147.85
		W	65.1	124.22	66.4	122.76	64.6	123.10	68.5	115.27	67.4	131.39	75.4	126.34	74.7	144.09
	30	B	65.1	119.43	66.4	118.94	65.0	119.12	68.5	112.09	68.1	130.09	75.4	121.78	74.8	142.69
		M	65.1	116.88	66.4	115.94	64.8	116.84	68.5	108.95	67.6	126.53	75.3	117.87	74.8	139.34
		W	65.1	113.69	66.4	111.76	64.6	114.19	68.5	101.43	67.4	118.56	75.4	111.86	74.7	135.54
28.0	15	B	66.4	183.33	67.2	179.63	65.9	181.98	69.2	199.44	69.0	199.77	76.1	216.28	76.1	216.90
		M	66.4	180.36	67.2	175.78	65.7	178.83	69.2	189.62	68.8	195.33	76.1	205.80	76.0	211.94
		W	66.4	175.44	67.2	172.80	65.4	173.85	69.2	174.41	68.6	190.88	76.1	187.18	75.7	204.97
	30	B	66.4	175.04	67.2	172.89	65.8	176.50	69.2	177.12	69.1	186.32	76.1	189.09	76.0	201.45
		M	66.4	170.99	67.2	167.02	65.7	173.17	69.2	165.26	68.8	182.32	76.1	178.26	75.8	198.12
		W	66.4	167.26	67.2	162.45	65.6	170.93	69.2	156.14	68.4	178.09	76.1	172.77	75.7	194.69
Mean of means			62.4	74.23	63.8	72.49	61.9	73.44	66.9	68.61	65.8	77.80	73.6	75.12	72.8	85.69

[1]Expressed as percent of solid cubic volume of log.
[2]B = Best, M = Mean, and W = Worst of the 12 rotational positions from 0° to 165° for the plane of the initial saw cut.

Table 5.—Volume[1] and value yield of various sawing methods[1] for logs 12 feet long, with a centrally located 1-inch-diameter cylindrical core defect, sawn with a 3/8-inch kerf

Diameter	Knots per log	Rotational position[3]	Cant		Decision		Live[2]	
			Volume	Value	Volume	Value	Volume	Value
In.			%	$/log	%	$/log	%	$/log
10	15	B		106		97		123
		M	104	112	99	100	114	134
		W		108		97		140
	30	B		113		96		122
		M	104	116	99	99	114	126
		W		115		106		119
12	15	B		91		92		112
		M	103	92	99	94	112	113
		W		92		96		113
	30	B		108		106		124
		M	103	106	99	105	112	113
		W		114		112		107
14	15	B		104	99	106		119
		M	103	104	99	104	108	120
		W		106	99	108		128
	30	B		108	99	105		113
		M	103	109	99	105	108	112
		W		109	99	104		104
16	15	B		98	100	98		111
		M	100	100	100	100	107	113
		W		99	99	99		114
	30	B		104	100	108		108
		M	100	102	100	102	107	103
		W		102	98	99		95
18	15	B		106	100	105		115
		M	104	104	99	103	109	114
		W		105	98	99		115
	30	B		102	100	98		111
		M	104	104	99	102	109	110
		W		102	98	105		107
20	15	B		105	99	100		111
		M	103	106	99	100	106	109
		W		106	97	100		108
	30	B		105	100	102		103
		M	103	106	99	102	106	101
		W		107	98	101		97
24	15	B		104	100	101		108
		M	102	104	99	100	105	106
		W		102	98	99		106
	30	B		105	100	102		103
		M	102	105	98	102	105	101
		W		104	96	102		95
28	15	B		103	99	100		105
		M	101	105	97	100	104	106
		W		104	95	100		105
	30	B		106	99	103		107
		M	101	105	98	103	104	101
		W		103	95	102		97
Mean of means			103	105	99	101	108	111

[1]Expressed as percent of a quadrant-sawn log of identical size and knot location.
[2]Live rip was omitted because all values were identical to live sawn values.
[3]B = Best, M = Mean, and W = Worst of the 12 rotational positions from 0° to 165° for the plane of the initial saw cut.

U.S. Forest Products Laboratory.

Lumber values from computerized simulation of hardwood log sawing, by D. B. Richards, W. K. Adkins, H. Hallock, and E. H. Bulgrin, Res. Pap. 356 FPL, For. Serv., USDA. 29 p. Madison, Wis.

Computer simulation sawing programs were used to study the sawing of mathematically modeled hardwood logs 10 through 28 inches in diameter by the live sawing and three 4-sided sawing methods. All 4-sided methods gave similar lumber values. Live sawing followed by live ripping, a live sawing refinement in which center-sawn boards are ripped, produced the highest lumber values in almost all cases.

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Table 6.—Volume and yield of various sawing methods[1] for logs 12 feet long, with a centrally located 4-inch-diameter cylindrical core defect

Diameter	Knots per log	Rotational position[2]	3/8-inch kerf: Cant Volume	Cant Value	Decision Volume	Decision Value	Live Volume	Live Value	Live rip Volume	Live rip Value	1/4-inch kerf: Live Volume	Live Value	Live rip Volume	Live rip Value
In.			%	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%	$/log
10.0	15	B	104	109	99	93	114	85	114	91	130	110	128	122
		M	104	104	99	95	114	87	105	91	130	108	128	118
		W	104	99	99	92	114	85	100	89	130	101	128	114
	30	B	104	114	99	96	114	106	114	106	130	129	130	143
		M	104	112	99	97	114	98	107	105	130	124	128	140
		W	104	106	99	100	114	101	100	103	130	120	128	145
12.0	15	B	103	100	99	96	112	109	110	116	123	102	121	109
		M	103	102	99	97	112	111	110	119	123	105	121	113
		W	103	102	99	95	112	109	110	116	123	104	121	113
	30	B	103	109	99	101	112	108	111	123	123	108	122	123
		M	103	107	99	103	112	103	110	115	123	105	121	119
		W	103	114	99	111	112	95	110	116	123	101	121	118
14.0	15	B	103	99	99	95	108	116	108	116	117	123	117	127
		M	103	103	99	97	108	108	107	115	117	115	116	120
		W	103	106	99	100	108	101	107	110	117	110	116	119
	30	B	103	110	99	101	108	108	107	123	117	111	116	126
		M	103	109	99	103	108	102	107	118	117	107	116	124
		W	103	107	99	102	108	95	107	112	117	97	116	114
16.0	15	B	100	97	100	99	107	112	107	112	117	126	117	126
		M	100	99	100	99	107	111	107	113	117	125	117	128
		W	100	98	99	97	107	102	107	111	117	118	116	127
	30	B	100	103	100	104	107	110	107	119	117	125	116	135
		M	100	101	100	102	107	101	107	114	117	116	116	129
		W	100	104	98	99	107	99	107	114	117	112	116	126
18.0	15	B	104	98	100	103	109	115	109	116	123	131	123	131
		M	104	99	99	101	109	115	109	116	123	129	123	129
		W	104	98	98	99	109	112	109	117	123	124	122	124
	30	B	104	99	100	101	109	112	109	120	123	124	122	134
		M	104	99	99	102	109	106	109	119	123	117	122	131
		W	104	97	98	100	109	101	109	116	123	111	122	125
20.0	15	B	103	98	99	100	106	114	106	114	118	125	118	125
		M	103	99	99	99	106	110	106	111	118	123	118	123
		W	103	99	97	97	106	110	106	110	118	122	117	123
		B	103	99	100	102	106	103	106	110	118	114	118	123
		M	103	101	99	102	106	99	106	111	118	110	117	122
		W	103	102	98	101	106	97	106	111	118	104	117	119
24.0	15	B	102	103	100	100	105	108	105	108	116	118	116	118
		M	102	102	99	100	105	107	105	107	116	117	116	117
		W	102	101	98	98	105	106	105	106	116	115	115	115
	30	B	102	103	100	102	105	103	105	109	116	110	116	116
		M	102	103	99	102	105	99	105	106	116	109	116	115
		W	102	101	96	102	105	94	105	101	116	107	115	113
28.0	15	B	101	102	99	99	104	105	104	106	115	115	115	115
		M	101	102	97	99	104	106	104	107	115	115	114	116
		W	101	102	95	98	104	106	104	106	115	113	114	114
	30	B	101	104	99	103	104	105	104	106	115	112	114	117
		M	101	103	98	102	104	101	104	106	115	108	114	115
		W	101	102	95	102	104	97	104	107	115	106	114	114
Mean of means			102.5	102.8	98.9	100.0	108.1	104.0	106.7	110.8	119.9	114.6	118.9	122.4

[1] Expressed as percent of a quadrant-sawn log of identical size and knot location.
[2] B = Best, M = Mean, and W = Worst of the 12 rotational positions from 0° to 165° for the plan of the initial saw cut.

Table 7.—Volume[1] and value yield of various sawing methods for 12-foot hardwood logs, with a centrally located 6-inch-diameter cylindrical core defect

Diameter	Knots per log	Rotational position[2]	3/8-inch kerf: Cant Volume	Cant Value	Decision Volume	Decision Value	Live Volume	Live Value	Live rip Volume	Live rip Value	1/4-inch kerf: Live Volume	Live Value	Live rip Volume	Live rip Value
In.			%	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%	$/log
10.0	15	B	104	79	99	42	114	70	114	70	130	57	130	57
		M	104	86	99	46	114	67	114	67	130	64	130	64
		W	104	95	99	51	114	74	114	74	130	73	130	73
	30	B	104	108	99	61	114	85	114	85	130	83	130	83
		M	104	98	99	65	114	78	114	78	130	90	130	90
		W	104	82	99	71	114	76	114	76	130	95	130	95
12.0	15	B	103	80	99	84	112	87	110	92	123	79	122	84
		M	103	83	99	85	112	85	109	91	123	76	121	80
		W	103	84	99	80	112	78	109	85	123	69	121	74
	30	B	103	91	99	95	112	86	111	101	123	86	122	92
		M	103	91	99	91	112	84	109	94	123	85	122	91
		W	103	96	99	97	112	84	109	94	123	92	121	96
14.0	15	B	103	99	99	91	108	97	100	109	117	104	115	111
		M	103	100	99	89	108	94	100	108	117	95	115	110
		W	103	105	99	91	108	92	100	108	117	92	115	107
	30	B	103	110	99	102	108	106	104	120	117	102	115	121
		M	103	102	99	98	108	93	101	112	117	94	115	114
		W	103	102	99	99	108	87	100	107	117	90	115	109
16.0	15	B	100	95	100	97	107	95	102	108	117	111	115	126
		M	100	96	100	96	107	94	102	107	117	110	115	123
		W	100	97	99	95	107	93	102	106	117	108	115	122
	30	B	100	99	100	98	107	96	102	110	117	108	116	127
		M	100	101	100	97	107	94	102	113	117	109	115	128
		W	100	101	100	95	107	89	102	109	117	104	115	124
18.0	15	B	104	97	100	99	109	99	108	113	123	115	122	128
		M	104	95	100	97	109	97	108	112	123	111	122	125
		W	104	95	100	95	109	97	108	111	123	103	122	118
	30	B	104	99	100	102	109	100	108	119	123	112	122	132
		M	104	99	100	99	109	99	108	119	123	109	122	130
		W	104	99	100	100	109	100	108	120	123	109	122	127
20.0	15	B	103	98	99	98	106	108	106	110	118	120	118	123
		M	103	98	99	97	106	101	106	110	118	115	117	122
		W	103	98	99	96	106	95	105	110	118	106	117	121
	30	B	103	99	100	99	106	93	106	110	118	111	117	121
		M	103	102	99	100	106	95	105	113	118	106	117	123
		W	103	106	99	104	106	93	105	112	118	103	117	125
24.0	15	B	102	98	100	99	105	108	105	109	116	119	116	119
		M	102	98	100	99	105	105	105	107	116	115	116	118
		W	102	97	99	98	105	101	105	106	116	122	115	117
	30	B	102	101	100	101	105	100	105	111	116	111	116	120
		M	102	100	99	101	105	98	105	109	116	108	115	120
		W	102	100	98	102	105	95	105	104	116	106	115	120
28.0	15	B	101	100	99	99	104	106	104	106	115	115	115	116
		M	101	99	98	99	104	106	103	107	115	115	114	116
		W	101	99	95	98	104	105	103	107	115	113	114	114
	30	B	101	100	99	101	104	108	104	108	115	110	114	119
		M	101	99	99	101	104	102	103	108	115	110	114	117
		W	101	99	98	102	104	98	102	108	115	109	114	115
Mean of means			102.5	96.7	99.3	91.2	108.[illegible]	93.2	105.9	103.4	119.9	100.8	118.7	110.7

[1]Expressed as percent of a quadrant-sawn log of identical size and knot location

[2]B - Best, M - Mean, and W - Worst of the 12 rotational positions from 0° to 165° for the plane of the initial saw cut

Table 8.—Volume[1] and value yield of various sawing methods for 12-foot hardwood logs, with a centrally located 8-inch-diameter cylindrical core defect

Diameter	Knots per log	Rotational position[2]	3/8-inch kerf: Cant Volume	Cant Value	Decision Volume	Decision Value	Live Volume	Live Value	Live rip Volume	Live rip Value	1/4-inch kerf: Live Volume	Live Value	Live rip Volume	Live rip Value
In.			%	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%	$/log
12.0	15	B	103	76	99	93	112	67	112	67	123	74	123	74
		M	103	65	99	95	112	66	112	66	123	67	123	67
		W	103	59	99	96	112	64	112	64	123	56	123	56
	30	B	103	65	99	100	112	72	112	72	123	76	123	76
		M	103	62	99	103	112	71	112	71	123	69	123	69
		W	103	66	99	112	112	71	112	71	123	69	123	69
14.0	15	B	103	97	99	96	108	75	107	80	117	75	114	100
		M	103	96	99	97	108	73	106	78	117	76	114	99
		W	103	96	99	99	108	67	105	74	117	77	114	100
	30	B	103	101	99	101	108	77	107	83	117	80	115	94
		M	103	98	99	101	108	75	105	81	117	75	114	94
		W	103	92	99	102	108	63	103	76	117	69	114	91
16.0	15	B	100	97	100	96	107	75	103	105	117	92	115	117
		M	100	95	100	96	107	74	103	104	117	90	115	116
		W	100	92	99	95	107	70	103	100	117	87	115	115
	30	B	100	95	100	97	107	75	105	104	117	90	115	113
		M	100	96	100	98	107	76	104	106	117	91	115	118
		W	100	96	99	94	107	74	103	102	117	88	115	119
18.0	15	B	104	104	100	96	109	96	108	114	123	107	121	121
		M	104	103	100	97	109	90	107	108	123	101	121	121
		W	104	103	100	96	109	85	106	106	123	96	121	118
	30	B	104	103	100	98	109	93	107	114	123	104	121	125
		M	104	103	100	98	109	88	106	111	123	101	121	123
		W	104	102	39	100	109	84	106	109	123	100	121	120
20.0	15	B	103	101	99	97	106	103	105	114	118	109	117	123
		M	103	101	99	98	106	100	105	110	118	108	117	122
		W	103	102	99	99	106	98	104	111	118	107	116	122
	30	B	103	99	100	99	106	89	105	105	118	97	117	116
		M	103	102	99	99	106	88	104	106	118	98	117	119
		W	103	107	99	102	106	90	104	110	118	100	116	122
24.0	15	B	102	98	100	98	105	97	105	106	116	106	115	117
		M	102	98	99	98	105	96	104	106	116	104	115	116
		W	102	99	99	99	105	93	103	106	116	102	115	116
	30	B	102	100	100	100	105	94	105	109	116	102	115	119
		M	102	99	100	100	105	93	104	108	116	101	115	119
		W	102	98	99	100	105	89	103	104	116	98	115	119
28.0	15	B	101	98	99	99	104	109	104	109	115	118	115	118
		M	101	97	99	99	104	105	104	108	115	114	114	118
		W	101	98	98	99	104	99	103	109	115	107	114	117
	30	B	101	99	99	101	104	101	104	106	115	108	114	115
		M	101	98	99	101	104	97	103	107	115	104	114	116
		W	101	97	99	102	104	93	103	106	115	103	114	116
Mean of means			102.3	93.8	99.3	98.6	107.3	84.1	105.6	90.3	118.4	92.8	117.0	108.3

[1] Expressed as percent of a quadrant-sawn log of identical size and knot location
[2] B = Best, M = Mean, and W = Worst of the 12 rotational positions from 0° to 165° for the plane of the initial saw cut

Table 9.—Mean values for 12-foot logs with a 1-inch-diameter core defect[1]

Diameter	Number of knots	Sawing method: Quadrant	Cant	Decision	Live[2]	Means	Mean
In.		$/log					
10	15	13 81	15 41	13 76	18 48	15 37	
	30	7 92	9 21	7 87	9 96	8 74	12 053
12	15	29 71	27 39	28 01	33 66	29 69	
	30	20 52	21 71	21 52	23 25	21 75	25 720
14	15	38 15	39 65	39 77	45 70	40 82	
	30	30 89	33 53	32 40	34 52	32 84	36 830
16	15	53 82	53 90	53 90	60 85	55 62	
	30	47 08	48 00	48 19	48 69	47 99	51 805
18	15	68 04	70 99	70 28	77 58	71 72	
	30	58 68	60 78	59 68	64 63	60 94	66 330
20	15	89 83	94 87	89 43	97 54	92 92	
	30	79 40	83 73	81 09	79 90	81 03	86 975
24	15	135 67	140 51	135 97	144 38	139 13	
	30	121 32	126 82	124 08	122 07	123 57	131 350
28	15	188 05	196 83	188 86	200 00	193 44	
	30	174 10	181 87	179 10	175 22	177 57	185 505
Means	15	77 13	79 94	77 50	84 77	79 84	
	30	67 49	70 71	69 24	69 78	69 30	
Mean		72 31	75 33	73 37	77 28		74 57

[1]Summarized from table 1
[2]Live rip values were identical to those of live sawing

Table 10.—Mean values for 12-foot log with a 4-inch-diameter core defect[1]

Diameter	Number of knots	Sawing method: Quadrant	Cant	Decision	Live	Live rip	Means	Mean
In.		$ log						
10	15	12 65	13 11	12 00	11 04	11 49	12 056	
	30	7 66	8 59	7 47	7 52	8 02	7 852	9 955
12	15	25 36	25 87	24 70	28 21	30 21	26 87	
	30	19 94	21 32	20 44	20 52	23 01	21 05	23 958
14	15	36 75	37 72	35 64	39 87	42 09	38 41	
	30	30 51	33 15	31 41	31 17	36 10	32 47	35 441
16	15	51 66	50 96	51 02	57 32	58 37	53 87	
	30	45 44	46 12	46 31	45 72	51 93	47 10	50 485
18	15	66 08	65 26	66 53	76 03	76 52	70 08	
	30	58 23	57 70	59 18	61 80	69 15	61 21	65 648
20	15	87 54	86 34	86 71	96 64	96 87	90 82	
	30	79 15	79 77	80 74	78 65	87 76	81 21	86 017
24	15	133 36	135 61	133 87	142 49	142 98	137 66	
	30	120 83	123 97	122 99	119 92	128 03	123 15	130 405
28	15	186 68	191 25	185 09	197 83	199 20	192 01	
	30	174 05	178 79	178 03	175 55	185 15	178 31	185 162
Means	15	75 01	75 77	74 45	81 18	82 22	77 72	
	30	66 98	66 68	68 32	67 61	73 64	69 04	
Mean		70 99	72 23	71 39	74 39	77 93		73 38

[1]Summarized from table 2

Table 11.—Mean values for 12-foot logs with a 6-inch-diameter core defect[1]

Diameter	Number of knots	Sawing method: Quadrant	Cant	Decision	Live	Live rip	Means	Mean
In.		$/log						
10	15	10.01	8.61	4.56	6.71	6.71	7.32	
	30	6.94	6.83	4.54	5.40	5.40	5.82	6.571
12	15	23.50	19.56	19.88	19.86	21.46	20.85	
	30	18.76	17.09	16.98	15.72	17.68	17.25	19.049
14	15	35.07	35.23	31.29	33.01	37.88	34.50	
	30	29.22	29.94	28.58	27.25	32.71	29.54	32.018
16	15	49.61	47.52	47.44	46.87	53.24	48.94	
	30	43.35	43.60	41.88	40.88	48.89	43.72	46.328
18	15	64.35	61.28	62.73	62.66	71.88	64.38	
	30	56.13	55.55	55.35	55.48	67.00	57.90	61.141
20	15	85.48	83.89	82.82	86.67	93.92	86.56	
	30	76.89	78.16	77.17	73.17	87.15	78.51	82.532
24	15	131.42	128.46	129.89	137.60	141.24	133.72	
	30	119.96	119.50	121.50	117.87	130.81	121.93	127.825
28	15	185.10	183.84	182.51	195.38	197.17	188.80	
	30	172.88	171.20	175.11	175.49	186.00	176.14	182.468
Means	15	72.94	71.05	70.14	73.59	77.94	73.13	
	30	65.52	65.23	65.14	63.91	71.95	66.35	
Mean		69.23	68.14	67.64	68.75	74.95		69.74

[1]Summarized from table 3.

Table 12.—Mean values for 12-foot logs with a 8-inch-diameter core defect[1]

Diameter	Number of knots	Sawing method: Quadrant	Cant	Decision	Live	Live rip	Means	Mean
In.		$/log						
12	15	17.71	11.57	16.85	11.77	11.77	13.93	
	30	15.38	9.54	15.84	10.86	10.86	12.50	13.215
14	15	30.27	29.10	29.51	22.03	23.74	26.93	
	30	27.30	26.76	27.46	20.45	22.19	24.83	25.881
16	15	44.69	42.34	42.74	32.94	46.46	41.83	
	30	40.47	38.90	39.48	30.85	42.84	38.51	40.171
18	15	59.23	61.09	57.63	53.35	64.03	59.10	
	30	53.92	55.55	53.03	47.28	59.89	53.93	56.500
20	15	80.22	81.13	78.58	79.86	88.60	81.68	
	30	74.71	76.12	73.87	65.76	79.56	74.00	77.841
24	15	127.09	123.96	124.42	121.50	135.06	126.41	
	30	116.88	115.94	116.84	108.95	126.53	117.03	121.717
28	15	180.36	175.78	178.83	189.62	195.33	183.98	
	30	170.99	167.02	173.17	165.26	182.32	171.75	177.868
Means	15	77.08	75.00	75.51	73.01	80.71	76.26	
	30	71.38	69.98	71.38	64.20	74.88	70.36	
Mean		74.23	72.49	73.45	68.61	77.80		73.31

[1]Summarized from table 4.

Table 13.—Percent by which dollar value of best rotational position exceeded that of worst rotational position for 12-foot logs with a 1-inch-diameter core defect

Diameter	Number of knots	Sawing method: Quadrant	Cant	Decision	Live	Means	Mean
In.		%					
10	15	24.8	21.8	24.4	9.8	20.20	
	30	38.7	36.9	25.7	41.7	35.75	27.97
12	15	10.4	8.5	5.6	9.2	8.42	
	30	21.9	15.3	15.4	40.8	23.35	15.88
14	15	13.4	11.9	11.9	5.6	10.70	
	30	13.7	12.8	15.0	22.8	16.08	13.39
16	15	7.5	6.6	6.0	4.7	6.20	
	30	6.8	8.4	16.2	22.2	13.40	9.80
18	15	4.9	6.8	11.6	5.1	7.10	
	30	9.4	9.4	2.4	13.5	8.68	7.89
20	15	5.4	4.1	6.2	8.0	5.92	
	30	10.1	7.9	11.8	16.3	11.52	8.72
24	15	2.6	4.5	4.7	4.6	4.10	
	30	5.2	5.6	4.7	14.7	7.55	5.82
28	15	4.6	3.6	5.3	4.3	4.45	
	30	4.0	6.9	4.9	15.5	7.82	6.14
Means	15	9.20	8.47	9.46	6.41	8.39	
	30	13.73	12.90	12.01	23.44	15.52	
Mean		11.46	10.69	10.74	14.93		11.95

Table 14.—Percent by which dollar value of best rotational position exceeded that of worst rotational position for 12-foot logs with a 4-inch-diameter core defect

Diameter	Number of knots	Sawing method: Quadrant	Cant	Decision	Live	Live rip	Means	Mean
In.		%						
10	15	15.9	28.4	17.2	17.0	18.0	19.30	
	30	26.4	35.5	21.5	32.8	30.1	29.26	24.28
12	15	8.1	5.9	9.8	7.8	8.3	7.98	
	30	16.8	12.5	6.9	32.3	23.2	18.34	13.16
14	15	12.4	5.4	6.9	28.5	18.6	14.36	
	30	9.4	12.0	9.1	24.0	20.4	14.98	14.67
16	15	6.2	4.9	8.9	16.2	7.2	8.68	
	30	7.2	6.2	12.1	15.5	11.5	10.50	9.59
18	15	5.0	5.7	8.5	7.8	3.5	6.10	
	30	7.3	9.9	7.9	18.8	10.6	10.90	8.50
20	15	4.2	4.4	7.1	7.5	7.1	6.06	
	30	9.8	6.4	11.1	16.3	9.6	10.64	8.53
24	15	2.8	4.6	4.8	4.9	4.7	4.36	
	30	5.2	7.0	5.2	15.3	13.8	9.30	6.83
28	15	4.1	4.2	5.1	3.8	3.5	4.14	
	30	4.0	6.2	4.9	12.3	3.9	6.26	5.20
Means	15	7.3	7.9	8.5	11.7	8.9	8.87	
	30	10.8	12.0	9.8	20.9	15.4	13.77	
Mean		9.0	9.9	9.2	16.3	12.1		11.32

Table 15.—Percent by which dollar value of best rotational position exceeded that of worst rotational position for 12-foot logs with a 6-inch-diameter core defect

Diameter	Number of knots	Sawing method: Quadrant	Cant	Decision	Live	Live rip	Means	Mean
In.		----------	----------	%	----------	----------	----------	----------
10	15	27.6	5.54	6.3	20.6	20.6	16.12	
	30	23.7	62.1	6.3	36.6	36.6	33.06	24.59
12	15	6.1	0.4	11.6	17.9	15.1	10.22	
	30	23.2	16.4	20.5	27.3	32.7	24.02	17.12
14	15	10.7	5.1	10.7	16.7	11.6	10.96	
	30	7.4	16.3	10.4	30.8	21.1	17.20	14.08
16	15	5.7	3.5	8.8	8.1	7.1	6.64	
	30	8.4	5.6	12.6	16.9	9.4	10.58	8.61
18	15	3.1	5.2	7.1	5.2	4.9	5.10	
	30	7.8	8.1	10.0	7.1	7.1	8.02	6.56
20	15	5.7	5.3	8.3	20.9	6.0	9.24	
	30	12.0	4.5	6.6	12.3	9.7	9.02	9.13
24	15	2.6	3.4	3.3	10.4	4.8	4.90	
	30	4.6	5.7	4.5	10.0	10.7	7.10	6.00
28	15	4.3	4.7	6.0	5.4	3.6	4.80	
	30	4.8	6.7	3.6	15.5	5.5	7.22	6.01
Means	15	8.2	4.1	7.8	13.1	9.2	8.50	
	30	11.5	15.7	9.3	19.6	16.6	14.53	
Mean		9.9	9.9	8.5	16.3	12.9		11.51

Table 16.—Percent by which dollar value of best rotational position exceeded that of worst rotational position for 12-foot logs with a 8-inch-diameter core defect

Diameter	Number of knots	Sawing method: Quadrant	Cant	Decision	Live	Live rip	Means	Mean
In.		----------	----------	%	----------	----------	----------	----------
12	15	2.8	31.2	0.4	8.7	8.7	10.36	
	30	16.0	14.0	3.1	18.0	18.0	13.82	12.09
14	15	6.6	8.3	3.5	19.3	15.9	10.72	
	30	9.2	19.9	8.4	33.8	19.3	18.12	14.42
16	15	5.7	12.1	6.4	12.8	10.2	9.44	
	30	9.9	9.1	12.9	11.6	12.4	11.18	10.31
18	15	4.3	5.2	4.3	17.1	12.0	8.58	
	30	7.0	8.1	4.9	18.1	11.7	9.96	9.27
20	15	5.9	4.0	3.5	12.1	8.5	6.80	
	30	11.5	3.6	7.8	9.9	5.8	7.72	7.26
24	15	3.6	2.4	2.7	8.2	4.3	4.24	
	30	5.0	6.4	4.3	10.5	9.7	7.18	5.71
28	15	4.5	4.0	4.7	14.4	4.7	6.46	
	30	4.7	6.4	3.3	13.4	4.6	6.48	6.47
Means	15	4.8	9.6	3.6	13.2	9.2	8.09	
	30	9.0	9.6	6.4	16.5	11.6	10.64	
Mean		6.9	9.6	5.0	14.9	10.4		9.36

Table 17.—Summary[1] of percent by which dollar value of best rotational position exceeded that of worst-rotational position for 12-foot logs

Diameter	Sawing method					Means
	Quadrant	Cant	Decision	Live	Live rip	
In.	%					
10	26.18	31.70	16.90	26.42	26.33	25.51
12	13.16	13.03	9.16	20.25	17.67	14.65
14	10.35	11.46	9.49	22.69	17.82	14.36
16	7.17	7.05	10.49	13.50	9.63	9.59
18	6.10	7.30	7.09	11.59	8.30	8.08
20	8.07	5.03	7.80	12.91	7.78	8.32
24	3.95	4.95	4.27	9.83	8.00	6.20
28	4.37	5.34	4.73	10.57	7.60	6.52
Mean	9.919	10.733	8.741	15.970	12.891	11.65

[1]Averages of 15- and 30-knot logs and of 1-, 4-, and 8-in.-diameter core defects.

Table 18.—Mean values per log (dollar value and percent of value for same log quadrant sawn[1]) as average of mean values for 15- and 30-knot logs with 1-inch-diameter core defects

Diameter	Sawing method							Means	
	Quadrant	Cant		Decision		Live			
In.	$/log	$/log	%	$/log	%	$/log	%	$/log	%
10	10.86	12.31	113.35	10.82	99.58	14.22	130.94	9.64	85.97
12	25.12	24.28	96.66	24.76	98.59	28.46	113.28	25.66	102.84
14	34.52	36.59	106.00	36.08	104.53	40.11	116.19	36.82	108.90
16	50.45	50.95	100.99	51.04	101.18	54.77	108.56	51.80	103.58
18	63.36	65.88	103.98	64.98	102.56	71.10	112.22	66.33	106.25
20	84.62	89.30	105.54	85.26	100.76	88.72	104.85	86.98	103.72
24	128.50	133.66	104.02	130.02	101.19	133.22	103.68	131.35	102.96
28	181.08	189.35	104.57	183.98	101.60	187.61	103.61	185.50	103.26
Means	72.31	75.29	104.39	73.37	101.25	77.28	111.67	74.56	105.77
Mean refigured from $/log means		104.12		101.47		106.87		103.11	

[1]From table 9; percent of quadrant values were calculated from $/log values.

Table 19.—Mean value per log (dollar value and percent of value for same log quadrant sawn[1]) as average of mean values for 15- and 30-knot logs with 4-inch-diameter core defects

Diameter	Sawing method									Means	
	Quadrant	Cant		Decision		Live		Live rip			
In.	$/log	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%
10	10.16	10.85	106.8	9.74	95.9	9.28	91.3	9.76	96.1	9.96	97.53
12	22.65	23.60	104.2	22.57	99.6	24.36	107.5	26.61	117.5	23.96	107.2
14	33.63	35.44	105.4	33.52	99.7	35.52	105.6	39.10	116.3	35.44	106.75
16	48.55	48.54	100.0	48.66	100.2	51.52	106.1	55.15	113.6	50.43	104.98
18	62.16	61.48	98.9	62.86	101.1	68.92	110.9	72.84	117.2	65.65	107.03
20	83.34	83.06	99.7	83.72	100.5	87.64	105.2	92.32	110.8	86.02	104.05
24	127.10	129.79	102.1	128.43	101.0	131.20	103.2	135.50	106.6	130.40	103.23
28	180.36	185.02	102.6	181.56	100.7	186.69	103.5	192.18	106.6	185.16	103.35
Means	70.99	72.22	102.46	71.38	99.84	74.39	104.16	77.93	110.59	73.38	104.26
Mean refigured from $/log means		101.73		100.55		104.79		109.78		103.37	

[1]From table 10; percent of quadrant values were calculated from $/log values.

Table 20.—Mean value per log (dollar value and percent of value for same log quadrant sawn[1]) as average of mean values for 15- and 30-knot logs with 6-inch-diameter core defects

Diameter	Sawing method									Means	
	Quadrant	Cant		Decision		Live		Live rip			
In.	$/log	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%
10	8.48	7.72	91.0	4.55	53.7	6.06	71.5	6.06	71.5	6.57	71.93
12	21.13	18.32	86.7	18.43	87.2	17.79	84.2	19.57	92.6	19.05	87.68
14	32.14	32.58	101.4	29.94	93.2	30.13	93.7	35.30	109.8	32.02	99.53
16	46.48	45.56	98.0	44.66	96.1	43.88	94.4	51.06	109.9	46.33	99.70
18	59.74	58.42	97.8	59.04	98.8	59.07	98.9	69.44	116.2	61.14	102.93
20	81.18	81.02	99.8	80.00	98.5	79.92	98.4	90.54	111.5	82.53	102.05
24	125.69	123.98	98.6	125.70	100.0	127.74	101.6	136.02	108.2	127.83	102.10
28	178.99	177.52	99.2	178.81	99.9	185.44	103.6	191.58	107.0	182.47	102.43
Means	69.23	68.14	96.56	67.64	90.93	68.75	93.29	74.95	103.34	69.74	96.04
Mean refigured from $/log means		98.43		97.70		99.31		108.26		100.74	

[1]From table 11; percent of quadrant values were calculated from $/log values.

Table 21.—Mean value per log (dollar value and percent of value for same log quadrant sawn[1]) as average of mean values for 15- and 30-knot logs with 8-inch-diameter core defects

Diameter	Sawing method									Means	
	Quadrant	Cant		Decision		Live		Live rip			
In.	$/log	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%
12	16.54	10.56	63.8	16.34	98.8	11.32	68.4	11.32	68.4	13.22	74.85
14	28.78	27.93	97.0	28.48	99.0	21.24	73.8	22.96	79.8	25.88	87.40
16	42.58	40.62	95.4	41.11	96.5	31.90	74.9	44.65	104.9	40.17	92.93
18	56.58	58.32	103.1	55.33	97.8	50.32	88.9	61.96	109.5	56.50	99.83
20	77.46	78.62	101.5	76.22	98.4	72.81	94.0	84.08	108.5	77.84	100.6
24	121.98	119.95	98.3	120.63	98.9	115.22	94.5	130.80	107.2	139.92	99.73
28	175.68	171.40	97.6	176.00	100.2	177.44	101.0	188.82	107.5	177.87	101.57
Means	74.23	72.49	93.8	73.44	98.5	68.61	85.1	77.80	98.0	73.31	93.84
Mean refigured from $/log means			97.66		98.94		92.43		104.81		98.76

[1]From table 12; percent of quadrant values were calculated from $/log values.

Table 22.—Mean volume[1] and value[2] yield for 12-foot hardwood logs of varying diameters and core defects

Log diameter	Core defect diameter	Sawing method							
		Cant		Decision		Live		Live rip	
		Volume	Value	Volume	Value	Volume	Value	Volume	Value
In.	In.	%							
10	1	103.7	113.4	98.9	99.6	113.5	130.9	113.5	130.9
	4	103.7	106.8	98.9	95.9	113.5	91.3	106.3	96.1
	6	103.7	91.0	98.9	53.7	113.5	71.5	113.5	71.5
	8	—	—	—	—	—	—	—	—
12	1	103.0	96.7	99.3	98.6	111.5	113.3	111.5	113.3
	4	103.0	104.2	99.2	99.6	111.5	107.5	110.2	117.5
	6	103.0	86.7	99.3	87.2	111.5	84.2	109.2	92.6
	8	103.0	63.8	99.3	98.8	111.5	68.4	111.5	68.4
14	1	102.8	106.0	99.0	104.5	107.5	116.2	107.5	116.2
	4	102.8	105.4	98.9	99.7	107.5	105.6	106.8	116.3
	6	102.8	101.4	99.0	93.2	107.5	93.7	100.7	109.8
	8	102.8	97.0	99.0	99.0	107.5	73.8	105.5	79.8
16	1	100.3	101.0	99.7	101.2	107.2	108.6	107.2	108.6
	4	100.3	100.0	99.7	100.2	107.2	106.1	106.8	113.6
	6	100.3	98.0	99.8	96.1	107.2	94.4	101.8	109.9
	8	100.3	95.4	99.6	96.5	107.2	74.9	103.4	104.9
18	1	104.3	104.0	98.8	102.6	109.3	112.2	109.3	112.2
	4	104.3	98.9	99.0	101.1	109.3	110.9	109.0	117.2
	6	104.3	97.8	100.0	98.8	109.3	98.9	108.1	116.2
	8	104.3	103.1	99.8	97.8	109.3	88.9	106.5	109.5
20	1	102.5	105.5	98.9	100.8	106.3	104.8	106.3	104.8
	4	102.5	99.7	98.9	100.5	106.3	105.2	105.9	110.8
	6	102.5	99.8	99.3	98.5	106.3	98.4	105.4	111.5
	8	102.5	101.5	99.1	98.4	106.3	94.0	104.5	108.5
24	1	102.0	104.0	98.8	101.2	105.2	103.7	105.2	103.7
	4	102.0	102.1	98.9	101.0	105.2	103.2	105.0	106.6
	6	102.0	98.6	99.5	100.0	105.2	101.6	104.8	108.2
	8	102.0	98.3	99.5	98.9	105.2	94.5	103.8	107.2
28	1	101.2	104.6	97.4	101.6	104.2	103.6	104.2	103.6
	4	101.2	102.6	97.7	100.7	104.2	103.5	104.1	106.6
	6	101.2	99.2	98.4	99.9	104.2	103.6	103.5	107.0
	8	101.2	97.6	98.9	100.2	104.2	101.0	103.6	107.5

Table 22.—Mean volume[1] and value[2] yield for 12-foot hardwood logs of varying diameters and core defects

Log diameter	Core defect diameter	Sawing method							
		Cant		Decision		Live		Live rip	
		Volume	Value	Volume	Value	Volume	Value	Volume	Value
In.	In.	%							
Means	1	102.5	104.4	98.9	101.3	108.1	111.7	108.1	111.7
	4	102.5	102.5	98.9	99.8	108.1	104.2	106.8	110.6
	6	102.5	96.6	99.3	90.9	108.1	93.3	105.9	103.3
	8	102.3	93.8	99.3	98.5	107.3	85.1	105.5	98.0
Mean of means		102.4	99.3	99.1	97.6	107.9	98.6	106.6	105.9
Column means		102.4	99.5	99.1	97.6	107.9	99.0	106.6	106.1

[1]Calculated from means in tables 1 through 4
[2]Summarized from percentage values in tables 18 through 21.
[3]Each item is the average of the mean for a 15- and 30-knot log, and is expressed as percent of a quadrant-sawn log of identical size and knot locations.

Table 23.—Value[1] of lumber produced from 12-foot logs of varying diameter, averaged for 15- and 30-knot logs and for 1-inch, 4-inch, 6-inch, and 8-inch-diameter core defects

Diameter	Sawing method								
	Quadrant	Cant		Decision		Live		Live rip[2]	
In.	$/log	$/log	%	$/log	%	$/log	%	$/log	%
[3]10	9.83	10.29	104.7	8.37	85.1	9.85	100.2	10.01	101.8
12	21.36	19.19	89.9	20.52	96.1	20.48	95.9	21.49	100.6
14	32.27	33.13	102.7	32.00	99.2	31.75	98.4	34.37	106.5
16	47.02	46.42	98.7	46.37	98.6	45.52	96.8	51.41	109.3
18	60.46	61.02	100.9	60.55	100.2	62.35	103.1	68.84	113.9
20	81.65	83.00	101.7	81.30	99.6	82.27	100.8	88.92	108.9
24	125.82	126.84	100.8	126.20	100.3	126.84	100.8	133.88	106.4
28	179.03	180.82	101.0	180.09	100.6	184.30	102.9	190.05	106.2
Mean	69.68	70.09	100.0	69.42	97.5	70.42	99.9	74.87	106.7
Mean refigured from $ log means	100.6	99.6		101.1		107.6			

[1]Values expressed as percent of a quadrant-sawn log of identical size and knot location.
[2]The live rip averages include values for 1-inch core logs. These values are omitted from tables 1, 5, 9, 13, and 18 because they are equal to live sawing values, but they are valid and are used in subsequent calculations as if they had been listed in those tables.
[3]The 10-inch-diameter log averages do not contain values for 8-inch core defects, as they were not used with 10-inch logs.

Table 24.— Summary percentages (tables 18-21) showing effect of weighting system on calculation of average percentages

Core defect diameter	Sawing method							
	Cant		Decision		Live		Live rip	
In.	Average of %[1]	% of average[2]	Average of %[1]	% of average[2]	Average of %[1]	% of average[2]	Average of %[1]	% of average[2]
1	104.4	104.1	101.2	101.5	111.7	106.9	111.7	106.9
4	102.5	101.7	99.8	100.5	104.2	104.8	110.6	109.8
6	96.6	98.4	90.9	97.7	93.3	99.3	103.3	108.3
8	93.8	97.7	98.5	98.9	85.1	92.4	98.0	104.8
Mean	99.3	100.5	97.6	99.6	98.6	100.8	105.9	107.4
Mean of means	99.9		98.6		99.7		106.7	

[1]Equal weighting for each log size.
[2]Weighted by dollar value.

Table 25.—Mean values per log (dollar value and percent of value for same log quadrant sawn) averaged for 15- and 30-knot logs and for 1- and 4-inch-diameter core defects

Diameter	Sawing method										
	Quadrant	Cant		Decision		Live		Live rip		Means	
In.	$/log	$/log	%	$/log	%	$/log	%	$/log	%	$/log	%
10	10.51	11.58	110.2	10.28	97.8	11.75	111.8	11.99	114.1	11.22	108.5
12	23.88	23.94	100.3	23.66	99.1	26.41	110.6	27.54	115.3	25.09	106.3
14	34.08	36.02	105.7	34.80	102.1	37.82	111.0	39.60	116.2	36.46	108.8
16	49.50	49.74	100.5	49.85	100.7	53.14	107.4	54.96	111.0	51.44	104.9
18	62.76	63.68	101.5	63.92	101.8	70.01	111.6	71.97	114.7	66.47	107.4
20	83.98	86.18	102.6	84.49	100.6	88.18	105.0	90.52	107.8	86.67	104.0
24	127.80	131.72	103.1	129.22	101.1	132.21	103.5	134.36	105.1	131.06	103.2
28	180.72	187.18	103.6	182.77	101.1	187.15	103.6	189.90	105.1	185.54	103.4
Means	71.65	73.76	103.4	72.37	100.5	75.83	108.1	77.60	111.2		
Mean refigured from $/log means		102.9		101.0		105.8		108.3			

Literature Cited

1. Adkins, W. K., D. B. Richards, D. W. Lewis, and E. H. Bulgrin.
1979. Programs for computer simulation of hardwood log sawing. USDA For. Serv. Res. Pap. FPL 357. For. Prod. Lab., Madison, Wis.

2. Bousquet, D. W.
1972. Sawing pattern and bolt quality effects on yield and productivity from yellow birch. For. Prod. J. 22(11):39-48.

3. Bousquet, D. W., and I. B. Flann.
1975. Hardwood sawmill productivity for live and around sawing. For. Prod. J. 25 (7):32-37.

4. Cummings, R., and H. W. Burry.
1969. Methods of sawing small hardwood logs. North. Logger & Timber Process. Sept. 1969, 12-30.

5. Flann, I. B.
1974. Converting hardwood logs. Can. For. Ind. 94(9):33-38.

6. Flann, I. B.
1978. Live sawing hardwoods. Can it mean dollars for you? Inf. Rep. OP-X-198E. Eastern For. Prod. Lab., Ottawa, Ont.

7. Flann, I. B., and D. W. Bousquet.
1974. Sawing live vs. around for hard maple logs. Inf. Rep. OP-X-91E. Eastern For. Prod. Lab., Ottawa, Ont.

8. Galliger, Lynn, and Hiram Hallock.
1971. Computer program for grading hardwood lumber. Unnumbered publ. USDA For. Serv., For. Prod. Lab., Madison, Wis.

9. Hallock, Hiram, and Lynn Galliger.
1971. Grading hardwood lumber by computer. USDA For. Serv. Res. Pap. FPL 157. For. Prod. Lab., Madison, Wis.

10. Huyler, N. K.
1974. Live-sawing: a way to increase lumber grade yield and mill profits. USDA For. Serv. Res. Pap. NE-305. Northeast For. Exp. Stn., Broomall, Pa.

11. Kersavage, P. C.
1972. Sawing method effect on the production of cherry lumber. For. Prod. J. 22(8):33-40.

12. King, W. W.
1956. Effect of sawing method on volume and value of 4/4 lumber from low-grade oak logs. Tech. Note No. 24. TVA, Div. For. Relat., Norris, Tenn.

13. Malcolm, F. B.
1961. Effect of defect placement and taper setout on lumber grade yields when sawing hardwood logs. U.S. For. Serv. FPL Rep. 2221. For. Prod. Lab., Madison, Wis.

14. Malcolm, F. B.
1965. A simplified procedure for developing grade lumber from hardwood logs. U.S. For. Serv. Res. Note FPL-098. For. Prod. Lab., Madison, Wis.

15. Murphey, W. K., R. S. Cochran, and R. E. Melton.
1972. A study in grade and live sawing graded cherry logs. North. Logger & Timber Process. 20(6):20-21, 24-27.

16. National Hardwood Lumber Association.
1978. Rules for the measurement and inspection of hardwood and cypress lumber. NLMA, Chicago, Ill.

17. Neilson, R. W., R. M. Hallett, and I. B. Flann.
1970. Sawing pattern effect on lumber recovery from high quality hard maple logs. For. Prod. J. 20(8):30-34.

18. Peter, R. K.
1967. Influence of sawing methods on lumber grade yield from yellow-poplar. For. Prod. J. 17(11):19-24.

19. Pnevmaticos, S. M.
1978. A case study in integrated utilization of hard maple. Inf. Rep. OP-X-195E. Eastern For. Prod. Lab., Ottawa, Ont.

20. Pnevmaticos, S. M., and D. W. Bousquet.
1972. Sawing pattern effect on the yield of lumber and furniture components from medium and low grade hard maple logs. For Prod. J. 22(3):34-41.

21. Richards, D. B.
1973. Hardwood lumber yield by various simulated sawing methods. For. Prod. J. 23(10):50-58.

22. Richards, D. B.
1977. Value yield from simulated hardwood log sawing. For. Prod. J. 27(12):47-50.

23. Richards, D. B.
1978. Sawing hardwoods for higher value. So. Lbrmn. 237(2942):9-12.

24. Richards, D. B., W. K. Adkins, H. Hallock, and E. H. Bulgrin.
1979. Simulation of hardwood log sawing. USDA For. Serv. Res. Pap. FPL 355. For. Prod. Lab., Madison, Wis.

25. Richards, D. B., H. Hallock, and E. H. Bulgrin.
1978. Optimum value yield from hardwood logs by simulated sawing. Proc. Symp. Simulation Techniques in Forest Operational Planning and Control. International Union of For. Res. Organ. Wageningen, Netherlands.

26. Richards, D. B., and J. A. Newman.
1979. Sawing high quality red oak logs. For. Prod. J. In press.

27. Robichard, Y., F. J. Petro, and M.C.S. Kingsley.
1974. Aspen lumber and dimension stock recovery in relation to sawing pattern. For. Prod. J. 24(3):26-30.

28. Saunders, H. W.
1979. Hardwood sawing process for increasing recovery and improving production. For. Prod. J. 29(2):21-29.

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